FINAL

Managing Magnetic Fields in California Public Schools

Submitted by

Brock Bernstein and H. Keith Florig
Principal Investigators

Laurie Geisinger, Max Henrion, John Jostes, Asher Sheppard
Co-investigators
to

California Department of Health Services
and the
Public Health Institute
1515 Clay Street, 17th Floor
Oakland, CA 94612

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Contract Officers:

Raymond R. Neutra, M.D., Dr.P.H.	Vincent Delpizzo Ph.D.
Chief, California EMF Program and Div. of Environmental & Occupational Disease Control	Director of Extramural Research California EMF Program

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Author Contact Information

Author	Mailing address	Telephone	Email
Brock Bernstein	308 Raymond Street Ojai, CA 93023	805-646-8369	brockb@west.net
H. Keith Florig	Department of Engineering & Public Policy Carnegie Mellon University Pittsburgh, PA 15213-3890	412-268-3754	florig@cmu.edu
Laurie Geisinger	Seattle City Light	206-386-4585	lgeiss@aol.com
Max Henrion	Lumina Decisions Systems 59 North Santa Cruz Avenue, Suite Q Los Gatos, CA 95030	408-354-1841	henrion@lumina.com
John Jostes	Interactive Planning and Management 30 West Mission Street, Suite 4 Santa Barbara, CA 93101	805-687-7032	jjostes@igc.org
Asher Sheppard	Asher Sheppard Consulting 108 Orange Street, Ste. 8 Redlands, CA 92373-4719	909-798-7791	AsherSheppard @compuserve.com

1. Background and Introduction

Studies of the possible health effects of electromagnetic fields (EMFs) from the electric power system[1] have been ongoing for almost 30 years. Although scores of studies have been completed on laboratory animals, cells, and human populations, unassailable evidence that EMF exposure is harmful has yet to emerge. In 1998, the National Institute of Environmental Health Sciences convened an expert working group to review studies of possible EMF health effects (NIEHS, 1999). This panel concluded that magnetic fields from power systems should be classified as possibly carcinogenic, on the basis of a number of epidemiological studies showing elevated risks of leukemia among children and workers exposed to unusually high magnetic field levels. The panel stopped short of characterizing the EMF-leukemia link as probable or proven because laboratory animal and cellular-level studies have not supported the observations in human populations. The panel further concluded that evidence linking EMF to diseases other than leukemia was either weak, sparse, or non-existent. This leaves open the possibility that diseases other than leukemia might be influenced by EMF exposure, although it may be quite some time before enough research is completed to permit experts to render a judgment one way or the other.

In 1993, the California Public Utilities Commission (CPUC) instructed the public utilities in California to support an EMF research and public education program (CPUC decision 93-01-013). The CPUC authorized the California Department of Health Services (CDHS) to carry out this program. The studies undertaken by this program (see http://www.dhs.ca.gov/ehib/emf) address a range of scientific and public policy questions. This report addresses one of those questions: What are the pros and cons of alternative policies to address EMF exposure in California public schools?

The California EMF Research Program has focused on schools for several reasons. First, of all the diseases that have been studied in relation to EMF exposure, the evidence for EMF-induced childhood leukemia risk is strongest, although not considered conclusive by scientific review panels (NIEHS, 1999; NRC, 1999). Second, society has historically set high standards for safety in schools and has shown a higher willingness-to-pay to protect children than to protect adults. Finally, the public school environment, unlike many other environments (e.g. home, work) is state-managed, so the state has a more direct institutional responsibility to manage EMF risks in schools compared to EMF risks in other areas.

[1] Power system EMFs arise from many indoor and outdoor sources including appliances, lighting fixtures, building wiring, transmission and distribution lines, electrical panels, and transformers. Although the term "electromagnetic field" technically refers to both electric and magnetic fields, concern about health effects has focused almost exclusively on exposure to magnetic fields. Further, Zaffanella et al. (2000) found that classroom electric fields resemble residential electric fields. In this report, we use the term "EMF" to refer only to magnetic fields.

Occupational risks incurred by teachers, although not the main driving force behind interest in EMF in schools, are also a consideration in the decision to study the EMF-in-schools problem.

The overarching goal of this project is to help policy makers and stakeholders evaluate alternative statewide policies to address EMF exposure in public schools. The project has four main products. The first (this document containing an Executive Summary and main report) identifies policy options at the statewide level and describes alternative frameworks for analyzing the pros and cons of those options. The second, a computer model called EMF_SCHOOL, allows stakeholders and decision makers to explore the statewide costs and benefits of alternative EMF field-strength standards for schools (Florig, 2000). The third is a brief orientation to using the first two products in actually making decisions. The fourth, a report on the social costs of a variety of diseases possibly associated with EMF exposure (Sheppard et al., 1998), provides background information to support analyses in the first two products.

Although many aspects of the EMF issue are similar to those involving other potential environmental hazards, EMFs in the environment are unique in a number of important ways. There are fundamental uncertainties about (i) whether EMFs are indeed hazardous and, (ii) if so, what measure of “dose” best predicts risk. Further, stakeholders involved in the EMF issue have very different opinions concerning how the scientific evidence should be interpreted, and different judgments concerning how society should respond under a given interpretation of the science. In this policy analysis, we explicitly recognize these legitimate differences of opinion. We decompose the larger policy questions posed by the EMF-in-schools problem into their component parts to help policy makers and stakeholders better understand which factors drive differences of opinion concerning policy choice. In addition, using the quantitative cost-benefit EMF_SCHOOL model mentioned above, we demonstrate how sensitive policy choices are to changes in various scientific or value judgments. Our goal in this document is not to recommend any particular policy, but rather to illustrate how various policy alternatives would be evaluated under a wide range of assumptions.

The intended audience for this document is decision makers with responsibility for developing and implementing relevant policy at the statewide level, including staff at the California Department of Education, School Facilities Planning Division; General Services Department, Office of Public Construction; Office of the State Architect; California Public Utility Commission; California Department of Health Services; State Legislature; electric utilities; and public interest groups. Such groups might use this report and its companion decision model to investigate the implications of proposed policies across a wide range of attributes; examine the effects of various tradeoffs among cost, exposure, mitigation method, and timing; explore how differences in values and assumptions affect the choice among policies; or assess the impacts of new knowledge about risk, exposure, and other factors.

This policy analysis is intended to provide a framework for thinking about a wide (but not exhaustive) range of *statewide* policy options for responding to EMF-related concerns in schools. This analysis does not (i) make an assessment of the level of health risks from EMF, (ii) evaluate the validity of concerns about such risks, or (iii) identify a preferred solution or solutions. The scientific uncertainties and the differences in values and perspective across stakeholders in problems as complex as this make it impossible to quantitatively derive a single "best" solution. Instead, recognizing that decision making about such complex issues involves scientific, social, ethical, economic, and procedural concerns (among others), this analysis strives to identify potential alternative policies and evaluate their qualitative and quantitative elements as a basis for informed decision making.

Some aspects of proposed policy options, such as cost, degree of exposure reduction, and health benefits, can be evaluated quantitatively using decision analysis tools such as EMF_SCHOOL. The purpose of this modeling is to estimate bounds on the costs and benefits of alternative management strategies and to explore how these costs and benefits change under various assumptions. Where uncertainty exists, as for example about the level of risk or the ultimate cost of exposure mitigation, the model allows for user input of a wide range of input parameters which may reflect expert judgment, a range of values derived from reliable sources, or differences in underlying values. The quantitative model is most useful, not as a predictor of actual outcomes, but as a means for structured exploration of the policy implications of different beliefs about EMF risk and/or the feasibility and effectiveness of various potential solutions. Thus the model provides a setting for improved communication and negotiation among stakeholders with differing views of the EMF problem. We have used the EMF_SCHOOL model to gain insight into a number of key questions regarding EMF policy for schools. These findings are reported later in this document. Individuals wishing to obtain a copy of the EMF_SCHOOL software may do so by contacting the California Department of Health Services.

The policy analyses comprising the rest of this document are organized as follows:

- Section 2 (EMF Exposure and School Risks) summarizes current knowledge about magnetic field levels in California schools, the sources that give rise to these fields, possible biological effects of EMF, and other non-EMF health and safety risks in schools.
- Section 3 (Decision Makers' Goals and Constraints) frames the analysis in terms that are both recognizable and relevant to decision makers
- Section 4 (Decision Scenarios) focuses the wide range of decision-making concerns onto a tractable subset of specific scenarios that provide a structure for discussing and analyzing the alternative policy options
- Section 5 (Alternative Policies for Statewide Response) describes a range of policy options that decision makers could use to achieve the desired outcomes described in Section 3. Some of

these options address specific decision scenarios outlined in Section 4, while others relate to all schools and all situations

- Section 6 (Quantitative Model of Field-Strength Standards) describes the EMF_SCHOOL model and presents model estimates of the health benefits and mitigation costs of field-strength standards for schools.
- Section 7 (Options for Funding) presents information about potential funding approaches to help assess the attractiveness and viability of alternative options
- Section 8 (Summary and Conclusions) distills the most important features of previous sections and synthesizes some overall lessons.

2. EMF Exposure and School Risks

This section provides brief background information on EMF levels in California schools, prominent sources of EMFs in schools, the health effects of EMF exposure, and non-EMF risks in schools. More detailed information on these subjects can be found in reference materials citied below. Much of our information on EMF levels and sources in California schools comes from an extensive series of measurements by Enertech Consultants (Zaffanella and Hooper, 2000). Under contract to the California Department of Health Services, Enertech made a detailed study of 89 quasi-randomly chosen California schools. The Enertech investigators measured EMF levels at thousands of points in and around each school and identified the major sources of magnetic field in each school area (e.g., classroom, playground). In addition, Enertech estimated the cost of reducing magnetic field levels from each of the sources identified in the 89 schools. Enertech's study used a carefully design sampling strategy intended to provide coverage of schools with and without large power lines, and schools serving different ages and geographic regions. Both the sampling and measurement protocol employed by Enertech were reviewed by outside parties before being finalized. Enertech's calculations of the costs of reducing magnetic fields from various sources are based on data from previously published reports as well as on information from outside electrical engineering consultants.

2.1 EMF sources and background levels

In their survey of 89 California schools, Enertech identified dozens of different sources of EMFs in classrooms, which Enertech classified along two dimensions (external/internal and area/operator) as shown in Table 2.1 below. Internal and external sources are those located within and outside the school building, respectively. Operator sources are sources that are used by one individual at a time (the operator) for which EMF exposure is generally limited to the period of use. Area sources are all sources, both internal and external, that are not operator sources.

Table 2.1. Enertech's classification scheme for sources influencing EMF exposure in schools. Some examples are listed for each category.

	Internal sources	**External sources**
Operator sources	Computers, electric pencil sharpeners, fish tank pumps, task lighting, overhead projectors	None
Area sources	Net current sources, electrical panels, power cables, transformers, fluorescent ceiling lights	Distribution lines Transmission lines

Findings of the Enertech study (Zaffanella and Hooper, 2000) that have particular relevance to the current report are:

- Magnetic field levels in classrooms average about 0.5 mG, but vary greatly from classroom to classroom. Based on the Enertech sample of 89 schools, it is projected that 4-8% of classrooms statewide (9,000-18,000 classrooms) have average field levels exceeding 2 milligauss. By comparison, a study of magnetic field levels in a quasi-random sample of 1000 homes nationwide (Zaffanella, 1993), found fields in U.S. homes to be slightly greater (0.6 mG average household) than fields found in California classrooms, and slightly more variable (15% of homes have average field levels exceeding 2 mG). Measurements conducted as part of a recent epidemiologic study of magnetic field exposure and spontaneous abortion in California found averages of 0.95 mG for indoor spot measurements in the homes of 506 women controls (Lee et al., 2001). Personal exposure measurements suggest that the time-average magnetic field exposures of individuals are somewhat higher than the spatial-average of the magnetic fields in the areas they inhabit. Another Enertech study measuring 24-hr personal exposure of 1,012 quasi-randomly selected individuals in the U.S. found time- and population-average exposures of 1.25 mG (Zaffanella and Kalton, 1998). Personal exposure measurements on a sample of 28 teachers in California schools yielded time- and population-average exposures of 1.02 mG for teachers working in a school near a 69 kV transmission line (N=13) and 0.69 mG for teachers working in a school without nearby power lines (N=15) (Lee et al., 1999). Personal exposure measurements made in conjunction with the spontaneous abortion study mentioned above found 24-hour time-weighted averages among 483 controls of 1.43 mG. The difference between personal exposure measurements and spatial measurements may be explained by the fact that the latter do not account for operator sources (e.g., electrical appliances, personal computers).

- Using data on the fraction of classroom area at or above a given field strength, and applying average occupancies of 22 students and 1.25 staff to each classroom, we estimate that <u>approximately 16,000 students and staff statewide (about 1% of all students and staff) are chronically (i.e., all day)</u>

exposed to magnetic fields of 5 mG or more at their desk location, whereas another 150,000 are exposed to magnetic fields of 5 mG or more for at least one period (~50 minutes) per day.

- By far, net currents are the largest contributor to the statewide average magnetic field level in classrooms. Net currents arise when supply and return currents in building wiring take different paths through the building. In their Table 8.39, Zaffanella and Hooper (2000) estimate that net currents contribute 70% of the classroom-milligauss above 0.5 mG.[2] Distribution lines are the next most important contributor to statewide average field levels, contributing about 8% of average classroom exposure above 0.5 mG. Other contributors and their contributions to average field levels are electrical panels (5%), transmission lines (4%), office equipment (3%), fluorescent lighting (2.2%), power cables (1.7%), power transformers (1.1%), and air conditioners and heaters (0.3%).

- Net currents are also the most common cause of unusually high magnetic fields in classrooms, accounting for 76% of the classrooms in which fields exceed 10 mG in at least 5% of the classroom area. Electrical panels are the next most common cause, accounting for 17% of the classrooms with fields exceeding 10 mG. Transmission line classrooms (defined as classrooms with transmission line fields > 0.5 mG in at least 5% of the area) have higher average fields than classrooms affected by other sources (i.e., having fields from other sources > 0.5 mG in at least 5% of the area), but the number of classrooms affected by transmission lines is small compared to the number of classrooms affected by other sources.

2.2 Evidence for EMF hazard

The scientific basis for assessing the health risks from EMF exposure are voluminous and have been reviewed elsewhere (NIEHS, 1999; NRC, 1999; Portier and Wolfe, 1998; Stevens et al., 1997). Despite three decades of epidemiological research on EMF health effects, considerable ambiguity exists concerning what diseases might be associated with EMF exposure. The conclusions of a recent study by the National Institute of Environmental Health Science are typical of the findings of a number of expert reviews conducted in recent years:

> *"The scientific evidence suggesting that ELF-EMF exposures pose any health risk is weak. The strongest evidence for health effects comes from associations observed in human populations with two forms of cancer: childhood leukemia and chronic lymphocytic leukemia in occupationally exposed adults. While the support from individual studies is weak, the epidemiological studies demonstrate, for some methods of measuring exposure, a fairly consistent pattern of a small,*

[2] Classroom-milligauss is a simple measure of population exposure obtained by summing over all ranges of field strength (e.g., 0.5-1 mG, 1-2 mG, etc.) the product of the number of classrooms in a given range of field strength and the mid-point field strength for that range (e.g., 1.5 mG for the 1-2 mG range).

increased risk with increasing exposure that is somewhat weaker for chronic lymphocytic leukemia than for childhood leukemia. In contrast, the mechanistic studies and the animal toxicology literature fail to demonstrate any consistent pattern across studies although sporadic findings of biological effects (including increased cancers in animals) have been reported. No indication of increased leukemias in experimental animals has been observed….."(NIEHS, 1999)

In short, experts that have reviewed the EMF bioeffects literature are uncertain about which, if any, diseases might be caused by EMF exposure, although the evidence linking EMF exposure to health is more substantial for some diseases (e.g. leukemia) than for others (e.g. melanoma). The California Department of Health Services has recently completed its own risk evaluation for EMF. It is important to note that the patterns that have been observed in human epidemiological studies reflect levels of individual risk that, if real, are comparable in magnitude to other health and safety risks for which regulatory agencies have taken action in the past (Florig, 1992).

This policy analysis does not argue for or against any particular point of view on the likelihood of EMF-related health risks. Rather, we consider a wide range of possible scenarios, and leave it to the reader to judge how likely a given scenario is likely to be. Our EMF_SCHOOL model of the benefits and costs of EMF field-strength standards described in Section 6, for instance, includes 21 different diseases in four age groups that are plausibly related to EMF exposure, based on literature reports (Sheppard et al., 1998). In Section 6, we present sensitivity analyses that explore the policy implications of assuming that EMF exposure is associated with any or all of these diseases.

In reviewing this report, the reader should keep in mind that any estimate of the risk reduction associated with an EMF exposure management policy are speculative because of numerous compounding uncertainties in the amount of EMF exposure reduction actually achieved by a given policy, which diseases are affected by EMF exposure, and the response of a given disease to changes in the EMF environment.

2.3 The "Exposure Measure" problem

There are two major sources of uncertainty in estimating the efficacy of any approach to EMF exposure management. First, as discussed above, scientists don't know whether or not magnetic fields at levels commonly found in schools are actually hazardous. Second, if magnetic fields are hazardous, scientists don't know what aspects of exposure are most predictive of risk. EMF exposures are dynamic. Not only do people move through spatially varying fields, but magnetic fields at any one location may change from moment to moment as a result of changing electrical loads within the school and on the power system. Currently available epidemiologic and laboratory studies have yet to identify what function of someone's personal exposure history will best predict EMF health risk. Although time-weighted average

(TWA) magnetic field exposure has been found to be predictive of risk in some studies, other studies suggest that changes in field intensity might be important as well. Still other studies suggest that a field strength threshold might exist below which there are no effects, or that biological effects might accrue only for exposures to fields within some narrow range of field strength (i.e. a "window" effect). Dealing with so many possibilities in a regulatory context is difficult, because actions that reduce one aspect of field exposure (e.g. the time-weighted average) may have only a limited effect on others (e.g. transient content). Thus, it is important for policy-makers to adjust downward estimates of risk reduction that are based on any one measure of exposure, to account for the possibility that other measures of EMF exposure might better predict risk. Given current scientific evidence, judgments of how large this downward adjustment should be are highly subjective. Nonetheless, our model provides an adjustment that the user can supply.

Some have pointed out that some mitigation strategies might be more robust than others by reducing "risk" under a wider variety of possible dose measures. For instance, eliminating transmission line fields from classrooms would be of no benefit if risk is dependent on transient content (rapid changes), since transmission lines carry few transients compared to other sources. Thus, the argument goes, one would be better off reducing exposures from other sources with higher transient content. This would make sense if transients were the only aspect of field exposure other than time-weighted average that might predict risk. However, there are many aspects of field exposure that are plausible candidates for the best predictor of EMF risk. If steady exposure to high fields should turn out to be more important than transients, then eliminating transmission line exposure could be more important than eliminating exposures from other sources. Because there remain so many possibilities, we argue that the best strategy is to apply a TWA measure to all sources and lower one's expectations for the estimated risk reduction according to one's judgment of the odds that some unrelated exposure measure is better. In this regard, we note that TWA field levels often have significant correlations with many alternative exposure measures when all sources are taken into account.

Our approach differs from that taken by another CDHS-funded policy project described in "Power Grid and Land Use Policy Analysis" by von Winterfeldt and colleagues (von Winterfeldt et al., 2001). That project (the "Land Use Project") examined residential EMF exposure, primarily from power lines. The Land Use project employed three different measures of EMF exposure: TWA, average field above a threshold, and time above a threshold. We argue that such distinctions are not useful in the schools case for two reasons. First, in the case of residential exposures to power line fields, populations at risk remain at a relatively fixed distance from the source of interest. Thus, it is plausible to quantitatively model the effects of different exposure measures on the risk reductions that would accompany a given mitigation measure. For the schools case, however, the populations at risk are quite mobile relative to various EMF sources and there are no data on how school populations move relative to various sources. Therefore, one cannot meaningfully model the effects of different exposure measures on EMF mitigation in schools. Second, for populations that are mobile relative to sources, population risk estimated using a TWA exposure measure provides a good approximation of population risk using any other exposure measure that is monotonic (never decreases) with increasing field strength. Thus, even if we had the mobility data needed to model non-TWA exposure measures in schools, we would not expect our predictions of population risk reduction for a given mitigation measure to differ significantly across the different exposure measures.

Some epidemiological studies of the childhood cancer risk of EMF exposure from power lines in residential areas have found that risk is better predicted by the “wire code” of the house than by EMF measurements made inside the house at the time of the study. (The wire code of a house is a scale that rates the house by the configuration of the local power line and its proximity to the house.) This has prompted suggestions that EMF management in schools might be based on modifying the wire codes of school areas, rather than reducing magnetic field levels *per se*. This is a bad idea for two reasons. First, work by Greenland and colleagues (Greenland et al., 1999) has shown that, when epidemiological studies of magnetic fields and childhood leukemia are considered as a group, magnetic fields are better predictors of risk than wire codes. Second, because studies showing significant correlations between risk and wire code involve homes and not schools, there are significant uncertainties concerning how well a wire code rating system would map into EMF risks in schools. Homes with high wire codes also have larger-than-average magnetic fields from distribution system neutral-to-earth currents in water and gas pipes. Such currents are a significant contributor to overall magnetic field levels in homes, but not in schools. Magnetic fields in schools arise mostly from sources that are unrelated to the distribution system. Those fields in schools that are from distribution systems are primarily fields from overhead wires themselves, not from currents not returning to the distribution transformer secondaries via the secondary neutral. Although the Enertech 89-school data show that magnetic fields in classrooms are, on average, higher for some wire codes, wire codes explain only a small portion (about 1%) of the classroom-to-classroom variation in magnetic field level. In our view, there is no reason to expect that wire code would be a better predictor of risks in schools than some field-strength measure.

In the remainder of this report, we use TWA magnetic field strength to characterize magnetic field exposure, and we assume that any health risk from magnetic field exposure is proportional to the TWA. This assumption implies that the population risk from exposing 10 persons to a TWA of 10 milligauss is the same as the population risk from exposing 100 people to a TWA of 1 milligauss. We also assume that exposing 10 people all day to 10 mG and another 10 people all day to 1 mG produces the same population risk as if all 20 people spent half the day in 10 mG and half the day in 1 mG.

2.4 Comparing EMF and Non-EMF risks in schools

Potential risks from EMF exposure in schools, while of great concern to some, are nevertheless only one of the many health and safety risks to which children are exposed while at school. These non-EMF risks are not the primary focus of this policy analysis and are explicitly addressed in only one of the alternative policy options described later. However, it is useful to have a sense of the relative magnitude of EMF and non-EMF risks at school.

Theoretical EMF Risks. As noted above, epidemiological studies have associated EMF exposure with a variety of rare and common health conditions. The decision models we have developed allow the decision maker to assign degrees of confidence of causality and effect sizes to all of these. The NIEHS working group assigned a “possible cause” to childhood leukemia, one of the rarer conditions. Since there is a published estimate of the theoretical population burden and added annual risks among the most highly exposed children, we will compare this theoretical added risk to other health risks in schools and discuss the implications of this comparison. In a recent meta-analysis of magnetic fields and childhood leukemia, Greenland and colleagues concluded that household magnetic field exposures averaging 3 mG and above convey an additional annual leukemia risk 1.7 times that of exposures averaging 1 mG or less (Greenland et al., 2000). Given background mortality rates for leukemia in California school children of 16 deaths per million per year (where field levels at home and school average 0.5 - 0.9 mG), annual excess leukemia risks among those with home exposures averaging 3 mG and above would be roughly 11 deaths per million.

School children spend less than 20% as much time in school as in their home. If, as we assume in our models, the weighted average of home and school time exposure best predicts disease risk, then the magnetic fields in schools would presumably convey a smaller excess risk to any given individual than equivalent fields at home (say 20% of 11 per million per year for leukemia). Note that 1-3% of classrooms in California (2,700-8,000 classrooms) have spatially-averaged magnetic fields exceeding 3 mG. Many thousands of other classrooms have at least 5% of floor space (the equivalent of one desk's location) with fields exceeding 3 mG.

Non-EMF Risks. It is useful to compare the potential EMF leukemia risks of the most highly exposed students (perhaps 2 excess deaths per million per year for school-time exposures of 3 mG and above) with the well-established non-EMF risks that children face. Considering both school and non-school time, the overall mortality risk for school children is about 250 per one million per year, with automobile accidents contributing the largest portion. A recent compilation of risks to middle school children (Florig et al., in press) estimated that annual mortality risks are roughly 70 per million for commuting to/from school, 20 per million for accidents at school (except sports), 10 per million for infectious diseases contracted at school, 8 per million for team sports activities, and 2 per million for intentional injury (i.e., violence). Thus, even for those school children exposed to the strongest EMF fields in the classrooms, it seems likely that EMF leukemia risks would be comparable to or smaller than other school and non-school risks that those children encounter.

These comparisons of EMF and non-EMF risks in school have implications for risk management that we discuss in detail later in this report. Briefly, those who subscribe to a “worst risks first” approach to risk management would argue that effort should be devoted to reducing the larger, non-EMF school risks before investing in EMF mitigation. Those who advocate using cost-effectiveness to allocate resources for risk reduction would call for studies of the costs of reducing non-EMF risks, before making any investments to mitigate risks at schools. Still others, who are more concerned with distribution of the total risk burden among schools, would argue that resources should go first to those schools bearing the greatest risk from all sources combined.

Recent studies by Morgan and colleagues (Morgan et al., in press) asked groups of lay persons to rank 22 different health and safety risks in a hypothetical middle school. Prior to ranking the risks, the groups were given briefing materials describing each school risk in considerable detail. Although the hypothetical school was situated near a transmission line, these groups tended to rank EMF risks as less serious than most of the other 22 risks. This suggests that the public, as a whole, might prefer that non-EMF risks in schools be addressed before EMF risks.

3. Decision Makers’ Goals

An important element of policy making is the process of understanding and weighing the positive and negative consequences of alternatives. This is often quite difficult, in part because only some consequences can be quantified in ways that permit straightforward tradeoffs. In the EMF case, for example, the degree of exposure reduction is more easily quantified than are potential effects on social discord and conflict (Tables 3.1 and 3.2).

Even more challenging is the fact that different stakeholders will perceive positive and negative consequences differently. What is a benefit to one group of stakeholders may be a negative consequence to another. Widespread efforts to reduce EMF exposure in schools might relieve the worries of parents concerned about potential health effects, be seen as a waste of money by those skeptical of EMF health effects, and be viewed by school officials as a lost opportunity to invest in other school improvements or as an administrative headache. Such differences often stem from fundamental disparities in core values that are deeply held and not easily influenced. Thus, economic efficiency may be most important from one perspective and fair process from another, even at the cost of reduced efficiency. Such value differences make it unfeasible to rank the costs and benefits of alternative policies in a consistent way that all stakeholders will agree with. For the decision maker, it therefore becomes impractical to choose a single "right" solution through an abstract analytical process or to achieve all goals simultaneously and to the same extent.

The preference of different stakeholders for different goals and the ways in which they approach tradeoffs depend largely on the value systems and assumptions implicit in each goal. Experienced decision makers are well aware of the fact that different people have different beliefs, opinions, and values. However, neither decision makers nor stakeholders themselves are always clearly aware of the way these differences derive from more fundamental differences in underlying value systems. Thus, discussions about alternative policies can cycle ineffectively if they do not at some point focus explicitly on underlying values. Doing so provides both decision makers and stakeholders with the opportunity to examine alternate ways of meeting these core values, thus lending flexibility to decision making. In addition, as Table 5.8 shows, different value systems lead to quite different ways of implementing the same policy. Having a conceptual structure for specifying these differences, and their specific implications for policy making, can improve the efficiency and effectiveness of decision making by elucidating the source of disagreements and providing suggestions for bridging gaps between stakeholders' points of view. In general, we believe that decision making is more effective the more readily it can focus on underlying assumptions rather than on more superficial disagreements about alternative policies.

The analyses of the policy options in Sections 5.2 and 5.4 include an examination of the implications of each policy for equity, fairness, and environmental justice. Despite the fact that these factors are impossible to quantify, they often carry more weight with stakeholders than more quantitative features such as exposure reduction and cost. Addressing such issues is thus an important goal for decision makers. In order to simplify the discussion of fairness and justice and make it more directly relevant to decision makers at the statewide level, we have framed it in terms of the two ends of a spectrum of values, utilitarian vs. ethical[1]. (The following discussion is a highly condensed summary of a large and complex literature on welfare philosophy. It is not intended to be exhaustive but merely to frame some fundamental approaches to thinking about key issues relevant to the EMF-in-schools issue.) Utilitarian approaches depend on an assumption that costs can be measured against benefits in a systematic and objective way, and that the goal of decision making is to create the greatest benefit for the greatest number of people. In utilitarian approaches to decision making, the selection of preferred options is therefore based on a comparison of the relative merits of alternatives. Ethical approaches place greater emphasis on how things ought to be, and on issues of fairness, equity, justice, and due process. Ethical approaches to decision making often refer to more ideal standards (such as fairness) and often rate most highly precisely those things that are the hardest to quantify.

There are many finer distinctions within these two broad categories, for example, between libertarian justice, which assumes that social arrangements have to provide for unrestrained interactions between free individuals, and social justice, which assumes that social arrangements must cater to the disadvantaged (Davy, 1996). While such distinctions are important in many circumstances (see Section 5.54 Implementation and its effects), for our purposes here we concentrate primarily on the tension between utilitarian and ethical concepts of decision making. The fundamental difference between these two approaches explains the conflict between those who believe that cost-benefit analysis should be the basis for choosing among risk management options for EMF exposure in schools and those who believe that costs and benefits cannot be captured objectively, that such a quantitative accounting system simply leaves out too much crucial information, and that quantitative modeling of complex decisions creates barriers to citizen participation.

Since quantitative decision modeling is a key part of this policy analysis, it is important that we explain how we believe it fits into the larger set of decision-making issues just discussed. We do not believe that all aspects of a complex problem such as EMF exposure in schools can be usefully quantified, nor that an optimum solution can be derived by a calculation of net benefits through cost-benefit analysis. We believe that differences in perspective and values among stakeholders are authentic. Further, we agree with Davy (1996) and others that social stability requires attention to diverse perceptions, the longer-term relationships among stakeholders, the distributive impacts of decisions, and the process by which decisions are made. Effective policy making therefore arises from a process of analysis, conflict, discussion, negotiation, and compromise (Adams, 1996). Decision analysis can make an important contribution to policy making by providing a framework for systematic analysis that makes explicit uncertainty and differences in values. The EMF_SCHOOL model described in Sections 6 is a significant step in this direction. The model helps resolve which assumptions and differences make a difference and which do not, thereby identifying more opportunities for agreement and compromise.

Tables 3.1 and 3.2 present a set of realistic goals for the outcome (Table 3.1) and process (Table 3.2) of EMF policy for schools. Each table contains some goals reflecting utilitarian values and some goals reflecting ethical values. These goals help provide the basis for the discussion of alternative policy options in Section 5 and a subset are analyzed more formally in subsequent sections. The goals presented below are based on our interviews with managers from utilities and schools (at the local and statewide levels) and public interest advocates, a review of the EMF literature, and the broader literature on policy and decision making. Based on this research, we believe that the relative importance of these goals will vary from situation to situation and across stakeholders. In addition, the way(s) in which policies are implemented has a significant influence on the degree to which they achieve decision makers' goals (see Section 5.5). Goals in Table 3.1 relate to the tangible outcomes of the policies themselves, and those in Table 3.2 to the process(es) through which policies are arrived at and implemented.

Table 3.1. .Goals that decision makers might have in developing and implementing policy on the EMF in schools problem. Goals shown here relate to the tangible outcomes of policies themselves.

Goal	**Description**
Reduce exposure	Reduce exposure to EMF and the possible health consequences of exposure. The relative importance of these goals and the extent to which they might be achievable depend on how uncertainties about health risks are perceived and/or resolved.
EMF exposure	Reduce exposure to school students and staff independent of proven health risks.
Disease and fatality risk	Reduce incidence of disease (morbidity) and deaths due to reduced EMF exposure, presuming EMF exposures cause health effects
Minimize costs	Minimize total dollar costs of risk-reduction
Survey and analysis	Costs of diagnosing the situation and deciding what to do
Engineering and construction	Costs of modifying electrical transmission and distribution facilities, and internal sources, including design, engineering, construction, materials, and labor
Administrative	Costs of administrative staff time and expenses in schools, local and state government, and legal costs Costs associated with making changes to the institutional infrastructure
Legal	Costs of litigation, liability insurance, liability judgments, delays due to litigation and/or fear of litigation
Healthcare	Costs of healthcare for those with diseases linked with EMF exposure
Miscellaneous social costs	Costs of shutting down power lines for modification, of decreased reliability of power lines from certain mitigations (e.g., tighter phase packing), of disruption to school budgets and functioning from surveying and fixing internal sources.
Maintain quality of education	Minimize disruption due to change in preferred usage patterns of classrooms and playgrounds to achieve exposure reduction Do not undermine funding of basic educational programs Minimize the diversion of student and school staff time and attention to EMF issues from educational activities
Distribute risks equitably	Distribution of risks among individuals, groups, subpopulations, schools, and school districts.
Within schools	Do not exacerbate any existing inequities in distribution of exposures to EMF and other possible hazards to individuals or groups within a school Equalize residual EMF exposures across individuals within a school
Between schools	Do not exacerbate any existing inequities between schools and school districts in distribution of exposures to EMF and other possible hazards Equalize residual EMF exposures across schools
Between groups	Do not exacerbate any existing inequities between ethnic and socioeconomic groups in terms of distribution of exposures to EMF and other possible hazards
Distribute costs equitably	Distribution of costs among individuals, groups, subpopulations, schools, and school districts
Within schools	Do not exacerbate any existing inequities in distribution of explicit and implicit mitigation costs among individuals or groups within a school
Between schools	Do not exacerbate any existing inequities between schools and school districts in distribution of explicit and implicit mitigation costs
Between groups	Do not exacerbate any existing inequities between ethnic and socioeconomic groups in terms of distribution of explicit and implicit mitigation costs

Table 3.2. Goals that decision makers might have in developing and implementing policy on the EMF in schools problem. Goals shown here relate to the process(es) through which policies are arrived at and implemented, as distinct from outcomes listed in Table 3.1

Goal	**Description**
Minimize social discord and conflict	Address public attitudes and perceptions that may lead to conflict among and between individuals and organizations
Reduce parental and staff worry	The degree to which parents of school children are worried about their exposure to risks of EMF
Build and maintain public confidence in leadership and institutions	Effects on public confidence in risk management institutions in business and government
Obtain public support of policy	Public participation in the policy development and implementation processes (environmental justice)
Ensure clarity of policy	Ease of public understanding of what the policy options are and how they will work
Promote fairness	
Within schools	Avoid unfunded mandates Public involvement efforts should have an identifiable influence on the outcome of any policy actions under review
Between schools	Compensatory justice approaches for prioritizing implementation among schools
Between groups	Compensatory justice approaches for choosing who should pay Ensure opportunities for equal access to decision-making process
Effectiveness	Apply best available information in decision making
Openness	Disseminate information equally to all parties

4. Risk Scenarios and Decision Settings

As the preceding and subsequent sections make clear, there is a wide range of decision-making concerns and an equally wide array of potential policy options available to address these. Each option can be implemented in a variety of ways, each with different impacts on cost and perceived fairness. Because the number of possible policy options are so large, analyzing every plausible permutation of goals, options, risk scenarios, and implementation pathways is infeasible. We have therefore described a set of representative risk scenarios and decision settings that provide a practical structure for organizing the discussion of policy options and the presentation of modeling results.

These scenarios can be helpful to users of this policy analysis in two further ways. First, the strength of belief in the various risk scenarios (Section 4.1) can help guide the user to one or another of the options most suited to that judgment about risk (see Table 5.1 and Table 5.7). Second, and in a similar way, the decision settings (Sections 4.2 - 4.5) can focus attention on the portion of the overall problem that is of most direct interest to them. This will help decision makers choose among the policies described in Section 5, and provides a context for interpreting the modeling results (Section 6).

4.1 Risk scenarios

The original problem statement for this policy analysis in the RFP laid out four possible outcomes of ongoing research on potential EMF health effects. The purpose of establishing such a starting point was to ensure that the policy analysis' results would be useful in evaluating alternative policies under a range of possible future situations. The four risk scenarios were:

1. Hazard identified; dose-response understood
2. Hazard identified; dose-response not understood
3. Present uncertainty persists
4. Non-EMF confounder explains away epidemiological findings.

It is not the purpose of this analysis to estimate the likelihood that one or another of these scenarios will take place or the time period in which this might happen. Rather, the policy analysis is designed to provide useful results that will support decision making across this entire range of outcomes. In particular, the quantitative decision models permit a user to choose the degree of uncertainty about risk and the timeframe within which they think such uncertainty might be resolved. This enables users to explore the implications and consequences of different assumptions about how the risk scenarios will be resolved.

Each of the policy options outlined in Section 5 is linked to one or more of these risk scenarios. Some options address only one risk scenario, while others cut across several.

4.2 Building a new school

There are several state agencies responsible for the review and approval of site planning, state-assisted financing, design, and construction of new schools. The California Department of Education (CDE) reviews and approves new school sites and additions to school sites that are paid for with state funds. The School Facilities Planning Division (SFPD) of CDE is responsible for ensuring that school districts applying for state school building funds comply with State Allocation Board policies regarding site acquisitions as outlined in the *Applicant Handbook: Lease-Purchase Law of 1976*. The SFPD has published another handbook, *School Site Selection and Approval Guides*, to assist school districts in selecting and gaining approval for new school sites. SDE approval of school sites is a normal prerequisite for state funding by the Office of Public School Construction. Given an average enrollment growth of about 63,000 students per year statewide and an average student population of 700 students per school (CALIF_DEPT_EDUC, 1997), the expected new school construction in California can be expected to be about 90 schools per year, of which about 75 would be elementary schools.

Among other things, the *School Site Selection and Approval Guides* addresses the location of new schools in relationship to high voltage power transmission lines, setting minimum distances for the location of the edge of school sites (not buildings) from high voltage transmission line easements. Minimum distances from power lines were originally established to guard against the risk that transmission towers would topple in earthquakes. While this risk has been effectively removed because of improved designs, these distances were increased in 1994 to additionally address concerns about EMF exposure and at that time were incorporated into Title 5, Section 14010 of the California Code of Regulations. The current distance limits, which are based on electric (not magnetic field) distributions, are:

- 100 feet from the edge of easement for 50-133 kV line. In the Enertech 89-school database, the magnetic field at 100 feet from the 30 lines of this voltage ranges up to 6 mG.
- 150+ feet from the edge of easement for 220-230 kV line. In the Enertech 89-school database, the magnetic field at 150 feet from the three lines of this voltage ranges up to 2 mG.
- 350 feet from the edge of easement for 500-550 kV line. The magnetic field at this distance ranges up to 10 mG (Sendaula et al., 1984).

The guide encourages selection of sites that meet these limits both at present and in the future. It thus advocates discussions with utility companies during the planning process to inform school officials concerning future utility plans to increase either voltage or the number of transmission structures on the easement. The guidelines, including the distance limits, are now part of the Education Code, Title 5, and as such are a regulatory requirement. However, there are two ways in which these guidelines might be avoided or set aside. First, schools that are financed with local, as opposed to state, funds need not apply to the CDE for site approval. While locally financed schools that do not comply with the guidelines might be subject to penalty in the future, there is no systematic program to audit locally financed sites nor is there a clearly defined set of penalties that apply to such situations. Second, school districts can appeal to the State Allocation Board, the parent agency of the Office of Public School Construction, for a waiver from the conditions in the guidelines. They may do so when even the most favorable of the available sites does not meet all the conditions. In such cases, the Allocation Board, which disburses funds, has occasionally granted waivers to the transmission line distance limits.

With the exceptions noted above, implementation of the site selection guidelines eliminates situations involving new school siting near utility transmission lines. There are factors that may limit the effectiveness of the guidelines, however, including:

- changes to utility power lines after construction of the school, such as the addition of extra circuits that carry additional current.
- addition of new transmission and high current distribution lines close to the school. There is no parallel requirement of the California PUC that requires utilities to observe the distances in the School Site Selection and Approval Guidelines
- inconsistencies in actual field strength in school buildings resulting from the application of a standard distance criterion that pertains only to the edge of the school site, not to the buildings themselves
- the fact that most health concerns are related to magnetic fields while the siting guidelines are based on electric fields.

In addition to site approval by the SDE, the Office of the State Architect has authority for checking building plan compliance with the State Building Code and the State School Construction Guidelines contained in Title 24. Schools that do not receive approval from the State Architect's office are not eligible for state construction funds. This provides a very real incentive for compliance with the Guidelines. The suitability of proposed school sites and plans is evaluated, negotiated, and resolved through discussions among the State Architect’s Office, the Department of Education and other involved parties (e.g., school districts, developers and other land owners, local architects and engineers).

4.3 Building/modifying a power line

This decision setting pertains to the construction of new transmission facilities and the significant modification of existing ones. As described in Southern California Edison’s EMF Design Guidelines for New Electrical Facilities, “New facilities will include, among others, additions, reroutes, rebuilds, and upgrades, such as reconductoring. These changes are commonly a part of capacity additions. It is not intended that the provisions of this guide … be applied to projects … that are of small magnitude.” It can be debated whether actions such as reconductoring should be classified as new facilities or modifications to existing facilities. We define this decision setting broadly to include all significant modifications to the transmission and distribution network, whether due to completely new construction or modifications of existing facilities. Where appropriate, we make finer distinctions in the description and analysis of specific policy options.

The State Constitution (Article XII, Section 6) gives the California Public Utilities Commission (CPUC) authority to regulate the siting and construction of new investor-owned (as opposed to public, or municipal) electrical facilities. Generally, the CPUC issues permits for transmission lines and substations that are either not otherwise explicitly provided for in local franchise agreements, or exceed a certain voltage or connect a new power source to the utility grid. The CPUC does not typically become involved in decisions pertaining to individual distribution lines. The recent deregulation of the utility industry and the creation of the California Energy Commission (CEC) has created an additional decision-making body. The CEC is responsible for issuing certificates of need for new generating facilities. Once a certificate is issued, it automatically substantiates the need for a transmission line to link the new generating station to the power grid. The CPUC then becomes involved in permitting the location of the transmission line. In general, the CEC is the lead agency on new generation and the CPUC on existing generation facilities. For example, the CPUC would be the lead agency on a new transmission line related to an existing generating facility and the CEC would have no jurisdiction in this instance.

Although none of the major decisions of the CPUC related to EMF have dealt directly with EMF in schools, several decisions indirectly affect schools. These are:

Order Instituting Investigation (91-01-012) which identified the EMF-related issues the CPUC intended to investigate and the goals it desired to achieve. This Order formally began the CPUC's "investigation of its potential role in mitigating possible health effects of electric and magnetic fields created by electric utility power systems." It also describes a range of strategies the CPUC might take in response to information about the potential health risks of EMFs. The Order also states that, "The appropriate agency to define the research needed to support such a conclusion [i.e., that a health hazard actually exists], to determine the status of current research, and to determine whether a scientific consensus exists about the nature of the public health risk, is a public health agency such as the Department of Health Services."

Decision 93-11-013 which 1) established no cost / low cost mitigation for new transmission and distribution lines and substations; 2) defined the upper range of low cost as four percent of total budgeted project cost ; 3) established a process and timeline for developing utilities' individual no-cost, low-cost EMF design guidelines for new and upgraded transmission projects; 4) authorized continued workplace EMF measurements; 5) authorized a four-year EMF education program with a budget of $1,489,000 and a research program with a budget of $5,600,000. This decision also stated that, "DHS is the appropriate agency to inform us as to the type of public health risk, if any, connected to EMF exposure and utility property and operations."

General Order 131 D which exerts jurisdiction of the PUC over utility lines of 50 kV and above, and lesser voltage lines if it determines this is necessary. It is not entirely clear what would happen in a situation where a local franchise agreement incorporated conditions that would be perceived as more limiting than the CPUC review and/or its prior decisions on EMF.

Kramer-Victor Decision (90-09-059) includes permit conditions the CPUC attached to construction of a 220 kV transmission line. These give a general indication of past practice, which some view as precedent setting for future projects. The conditions required the utility to choose the routing option furthest from people when choosing among options of equivalent cost and to notify people about EMF and their exposure. The decision also made the finding that EMF health risks are too speculative to assess in CEQA documents, noting that the CPUC has other authority under which it can manage EMF.

In most cases, low-cost and no-cost EMF mitigation measures are incorporated into new transmission lines, using the 0 – 4 percent guideline established in CPUC Decision 93-11-013. As described in the definition cited at the beginning of this section, additions, reroutes, rebuilds, and upgrades, such as reconductoring are considered “new” and therefore subject to the four percent rule. However, if there are no low-cost measures suitable for a specific transmission line, then utilities are not required to implement high-cost EMF mitigation measures.

Although some municipal utilities voluntarily conform to decisions and policies of the CPUC related to EMF, for example, the adoption of low field design guidelines for transmission and distribution, they are bound to the requirements of the Municipal Utility District Act (Public Utilities Code of the State of California, Division 6) and local franchise agreements. A municipal utility’s service territory can include more than one local government entity, for example a combination of cities and one or more counties. Generally speaking, municipal utilities enjoy somewhat more flexibility than investor owned utilities because the rule-making process is less formal than the CPUC’s and their decision making is not necessarily susceptible to statewide scrutiny. However, they may also have to meet a wider range of local requirements as there is no statewide agency acting to set common standards.

A key feature of this decision setting is that there are no siting guidelines or constraints that match the siting guidelines for new schools enforced by the Department of Education (see Section 4.2). On occasion, power lines and/or substations have therefore been approved and constructed adjacent to existing schools at distances that would have been a violation of the CDE’s siting guidelines if the situation had been reversed (i.e., building a new school near an existing power line). The statewide impact of this inconsistency in siting policy is probably small because the overall rate of construction of new power lines and substations in California is low. For example, between 1987 and 1996, transmission line construction averaged 161 miles a year, statewide, with a low of 0 miles and a high of 513 miles. Similar information on planned future construction is not available. However, Southern California Edison plans to construct less than 2 miles per year of new transmission lines from 1998 through 2003, with equally minor amounts of upgrades and relocation of existing transmission lines.

4.4 Existing schools and existing power lines

Existing transmission lines are those not covered by CPUC Decision 93-11-013 or General Order 131D and therefore not subject to either EMF mitigation requirements or formal CPUC review. While recognizing that there is concern about potential health effects of EMF, the CPUC in Decision 93-11-013 determined that scientific evidence did not yet warrant specific policies regarding existing lines. As a result, there is no formal decision-making structure that assists schools in addressing concerns about EMF exposure from existing transmission lines.

There are about 7900 public schools in the state. About 12-18% of these schools are on property that lies within 100 feet of a transmission line (CALF_DHS, 1996; Zaffanella and Hooper, 2000). All school properties have distribution lines nearby, from which they draw their electrical service. Despite the large fractions of schools near transmission and distribution lines, the fraction of classrooms with significant fields levels from power lines is quite small. For instance, Enertech estimates that only about 0.05% and 0.5% of the classrooms in the state have spatially-averaged fields greater than 2 mG from transmission and distribution lines, respectively (Zaffanella and Hooper, 2000) .

Transmission and distribution lines in close proximity to schools have occasionally raised concerns among parents and school staff about potential health risks to school children. However, as mentioned above, there is no regulatory structure that specifically addresses these situations. Each school district is responsible for the children in its care and for enforcing, on its own, relevant health and safety, building code, and other regulations. Unlike the workplace, where CalOSHA has statutory authority to regulate health and safety concerns, there is no agency with analogous statewide oversight and enforcement authority over such concerns in schools where children are involved. However, CalOSHA’s authority does provide an avenue for addressing EMF concerns where school staff are involved (although occupational standards for EMF are far higher than the levels typically encountered in schools). To the extent that student and staff exposures are similar, this provides an indirect pathway for dealing with students’ exposures. Thus, local decision makers can respond in a variety of ways when concerns arise in this decision setting.

Individual schools and school districts can request EMF surveys from their local utilities, under CPUC Decision 93-11-013 and the existing policies of most municipal utilities. However, they must themselves arrange for any additional survey or engineering studies needed for more in-depth investigation. They must also pay mitigation costs out of their own budgets. When asked by the local health department, CDHS may provide additional information and technical support. However, this has occurred in only a handful of cases. In a very few cases, individual schools have received extensive assistance from utility staff in dealing with unique situations, some involving apparent clusters of health problems. This decision setting is thus characterized by large variability at the level of individual school districts in the way concerns about potential health risks are addressed.

4.5 Internal sources

A detailed data summary and analysis of fields from internal sources can be found in the Enertech report (Zaffanella and Hooper, 2000). Internal sources in schools fall into two categories: operator sources and area sources. Operator sources are stand-alone pieces of equipment like appliances and video terminals, in which the major exposure concern is to the person who is actually using (operating) the source. The Enertech database contains a lengthy list of types of operator sources found in the surveyed schools. Area sources by definition are everything that is not an operator source. Power lines are area sources, but are not internal sources. Internal area sources include, for example, net currents, power supply cables, transformer vaults, distributed ceiling lighting, electrical closets, and subpanels.

As described in Sections 2.1 and 6.7.1, the Enertech study (Zaffanella and Hooper, 2000) found that internal sources are the dominant contributors to classroom average fields statewide, even when just considering classrooms with average fields greater than 5 mG (although, for schools situated near transmission lines, there are cases in which the transmission line fields are the dominant source of elevated classroom field levels). For instance, using the field criterion of 5 mG, 93% of the classrooms in this category are due to internal sources while only 7% are attributable to transmission lines. If 0.5 mG is used, then 87% are attributable to internal sources, 11% to distribution lines and only 2% to transmission lines.

There are no regulations or voluntary guidelines that bear on EMF exposure from operator sources at field levels relevant to schools, except the voluntary EMF guidelines from Sweden that some manufacturers of video display terminals (VDTs) have adopted. The most pertinent existing regulation is the National Electrical Code (NEC) which specifies how circuits are to be wired to minimize risk of electrical shock, fire, and damage to electrical equipment. All internal area sources are covered by the NEC, but the code is relevant to EMF mostly for net currents. This is because the most common cause of net currents is an NEC violation such as connecting the neutral wires of multiple circuits together at a point other than a subpanel. In fact, as noted in Section 2.1, the Enertech study found that the single most common source of elevated fields in school areas occupied by pupils, teachers, and staff was net currents due to improper wiring. Most (80%) of the improper wiring constituted violations of the National Electrical Code. While the State Architect's office reviews plans for new schools to ensure that these comply with the California Building Code requirements for earthquake safety and the Americans With Disabilities Act, it is important to note that there is no regulatory requirement that schools comply with the provisions of the NEC, nor is there any mechanism for inspecting schools after they are built to determine if they were built with or remain in compliance with the Code.

Recent policies mandating reduced class sizes in California schools have in some cases required the use of portable classrooms to accommodate the need for additional classrooms. There have been some concerns expressed that portable classrooms might have higher fields because heating and air conditioning systems, as well as the power conditioning equipment associated with these facilities are typically mounted directly on the exterior of the unit. Other concerns have focused on the possibility that portable classrooms might be situated close to the school property lines and therefore have higher EMF exposure from transmission or distribution lines adjacent to school property. Enertech's measurements of magnetic field levels in portable and regular classrooms, however, show that regular classrooms have slightly higher magnetic field levels than portables. Spatially-averaged fields in regular and portable classrooms are .56 mG and .49 mG, respectively. Ninety-fifth percentile fields are 1.35 mG and 1.19 mG, respectively.

Portable classrooms aside, older schools in general are more likely to have elevated fields from internal sources. According to the Enertech survey results (Figure 8.34 in Zaffanella and Hooper 2000), median classroom fields for schools in the lowest SES category are about 0.25 mG higher than the median field for all other SES categories combined. This is partly because wiring hardware and practices have changed over the years, but more commonly because old schools have had many modifications done to their wiring, and those modifications are often miswired in such a way as to produce a net current source. Although new schools have fewer such problems, they are not immune to the accumulation over time of wiring modifications and resulting increases in internal fields from this source. Given that the marginal cost of control increases with decreasing field strength, the most cost-effective opportunities for exposure reduction will be found at low SES schools.

Currently there two sources of information about measures that could be incorporated into building and electrical codes as low EMF design features for schools. These are the *EMF Checklist for School Buildings and Grounds Construction* (CALIF_DHS, 1999) and a video on wiring errors in schools, both produced by the California EMF Program.

5. Alternative Policies for Statewide Response

There are a variety of ways in which decision makers could achieve the goals described in Section 3. This section describes and analyzes a range of sample policy options that can help achieve these goals. These options cover categories of policies likely to be considered under the different risk scenarios. In addition, the CPUC has stated explicitly that, depending on the nature of future information about risks from EMF, it "may change its existing rules, regulations, and policies regarding the operation, design, construction or siting of electric utility power facilities … and will consider whether additional research should be undertaken or funded by California investor-owned utilities" (OII 91-01-012).

The options described here respond to this charge and include technology-based standards or guidelines, modifications of existing processes, and procedures for informing stakeholders and involving them in decision making. Some options address specific decision scenarios outlined above (Sections 4.2 - 4.5), while others relate to all schools and all situations. In general, we identified options that represent a variety of different approaches (e.g., health-, cost-, equity-based) and address a range of sources (i.e., transmission, distribution, internal). In any particular instance, the option(s) selected for consideration, and the one(s) finally selected, will depend on perceptions of the likelihood of various risk scenarios (see Section 4.1), the specific setting (see Sections 4.2 - 4.5), and the way decision makers resolve the inevitable conflicts among their goals. In addition, the particular pathway(s) chosen for implementation will significantly impact the distribution of costs and risks and therefore the perceived fairness of any option. As a result, it is not possible to define, ahead of time, a set of preferred options for specific situations. Instead, we present a discussion of the strengths, weaknesses, and implications of each option as an aid to decision making. In general, our discussion addresses the topics outlined in Box 1, and is separated into descriptions of the individual options followed by analyses of key cross-cutting issues such as cost, risk reduction, and administrative feasibility. We identify where agencies' existing authority provides a basis for implementation but stop short of discussing more detailed issues of compliance and enforcement.

Box 1: Topics Addressed in Description and Analysis of Policy Options

- Title
- Description
- Technical considerations
- Relationship to existing authority and authorizing agency; need for new authority
- Implementing agency
- Relationship to existing EMF and analogous policies
- Key uncertainties
- Administrative effort
- Source of funding (if applicable)
- Potential for exposure/risk reduction (if applicable)
- Costs
- Implications for fairness / environmental justice
- Implications for liability and potential litigation
- Adaptability to future changes in knowledge
- Relationship to other options

We divide the policy options into two broad categories - those intended to directly reduce risk (e.g., field standards) and those that indirectly may reduce risk by improving information quality and its availability, strengthening communication processes, or changing procedural aspects of decision making. Of the 13 options presented, 10 apply to both internal and external sources, one applies to external sources only, one applies to internal sources only, and one applies to siting both schools and power lines. Policy options considered vary in scope from narrow (e.g., enforcing some provisions of the National Electrical Code) to comprehensive (e.g., statewide program to reduce all health and safety risks in schools). Thus, the implementation steps needed to put each policy in place vary greatly from option to option. In any specific situation, policy options might be combined or implemented in sequence to achieve certain outcomes, since, except for the first (*Eliminate Existing EMF Programs*), they are potentially complementary. In fact, as discussed below (Section 5.4 Implementation and its Effects), under certain risk scenarios various exposure reduction options would probably be implemented in tandem with communication and procedural options that would help the exposure reduction policy proceed more smoothly.

For each option, there are in addition many possible variations based on alternative pathways for implementation (Section 5.5) and/or funding (Section 7). In particular, we recommend that readers see Section 5.5 for frameworks for combining and/or sequencing the various options. The descriptions in this section therefore present the essential features of each policy option. They are not intended as exhaustive descriptions of every possible combination of hazard scenario, decision setting, specific option, implementation pathway, and funding mechanism.

5.1 Exposure reduction options

The existing school siting guidelines assure consideration is given to a number of siting criteria. Among other things, the guidelines serve to keep new schools away from existing electric transmission lines. There are, in addition, other statewide policies that can affect the exposure to EMFs within schools and decisions about how to manage risk and exposure reduction policies. The National Electrical Code specifies construction and wiring standards that, when followed, largely prevent exposure from internal area sources. General Order 131-D of the California Public Utilities Commission provides a regulatory basis for permitting transmission lines larger than 50 kV and CPUC Decision 93-11-013 sets out specific mitigation, informational, and research policies. The California Environmental Quality Act (CEQA), and the CPUC's policies for implementing it, furnish review procedures that could be used to address concerns about EMF. Finally, the California EMF Program has produced the *EMF Checklist for School Buildings and Grounds Construction* (CALIF_DHS, 1999), which contains many low-cost and no-cost mitigation measures.

Despite the number of policies relevant to EMF in general, the school siting guidelines represent the only statewide policy that has been enacted to focus specifically on managing or reducing exposures to EMFs in schools, from either external or internal sources. This leaves open for debate potentially contentious situations in three of the four decision settings described above (Sections 4.2 - 4.5), such as the construction or upgrading of power lines near existing schools, concerns about exposures at existing schools near existing power lines, and internal sources.

In Sections 5.1.1 through 5.1.8, we present eight policy options that could help structure decision making in the three decision settings mentioned above. While the first (*Eliminate EMF Programs*) treats the situation in which EMFs could be disregarded entirely, the remaining options consider strategies that assume the existence of risk or potential risk from EMF exposure. Table 5.1 shows the distribution of the alternative policies across the hazard scenarios and decision settings defined in Section 4.

Table 5.1. Distribution of the eight exposure and potential risk reduction options across the risk scenarios and decision settings defined in Section 4. While cost options are relevant across a gradient of settings and scenarios, we show the most likely application to highlight distinctions among the options. Section numbers in parentheses refer to the report sections where each option is described.*

Decision Settings	**Risk Scenarios**			
	Hazard and Dose Response Understood	**Hazard and Dose Response Not Understood**	**Hazard Uncertainty Persists**	**No Hazard**
New School	Field Standards (5.1.4) Personal Standard (5.1.5) Tech. Standards (5.1.6) All Risks (5.1.8)	Field Standards Tech. Standards Enforce Electrical Code (5.1.7) All Risks	Status quo (5.1.2)	Eliminate Programs (5.1.1)
Build or Upgrade Line at Existing School	Field Standards Personal Standard Tech. Standards All Risks	Prohibit Increases (5.1.3) Field Standards Tech. Standards All Risks	Status quo Prohibit Increases	Eliminate Programs
Existing School and Power Facilities	Field Standards Personal Standard Tech. Standards All Risks	Prohibit Increases Field Standards Tech. Standards Enforce Electrical Code All Risks	Status quo Prohibit Increases	Eliminate Programs
Local and Internal Sources at School Site or in Buildings	Field Standards Personal Standard Tech. Standards Enforce Electrical Code All Risks	Field Standards Tech. Standards Enforce Electrical Code All Risks	Status quo Enforce Electrical Code	Eliminate Programs

* References to sections with policy descriptions are shown in parentheses at the first appearance in the table.

5.1.1 Option 1: Eliminate existing EMF programs

This option is a return to construction and operation of schools and nearby utility facilities without regard for EMF exposures. This policy would be relevant under risk scenario #4 in which a non-EMF factor explains the epidemiological findings. As a result, a clear scientific consensus would hold that EMF exposure presents no known risk. Eliminate Programs could apply in all four decision settings.

Existing policies and programs that directly or indirectly address public concerns about EMF in schools would be amended. For example, the *State School Site Selection and Approval Guide* would be revised by the Schools Facilities Planning Division to remove provisions for minimum distances between school property and electric transmission lines except as they affect electrical (as distinct from EMF) safety. The Legislature would remove references to these distances from Title 5 of the California Code of Regulations and replace them with the older minimum distances based on hazard from toppling transmission towers. Similarly, the Office of the State Architect would discontinue assessing compliance with such guidelines in its review of school building plans. The CPUC would reverse its interim decision 93-11-013. Electric utilities would discontinue providing EMF measurements to schools. Both utilities and the CPUC would cease considering EMF field design guidelines, from the perspective of potential health risks, in the construction of new transmission and distribution facilities. Finally, the California Department of Health Services would no longer consider potential EMF risks in its risk assessment and management efforts.

These actions would also include communication by the California Department of Health Services and other agencies explaining to concerned stakeholders, primarily parents and school officials, the reasons for removing existing EMF-related policies. Ongoing support would be needed during a transition period in which schools, utilities, and local health agencies may face concerns stemming from residual uncertainty. These communication and support activities would help develop understanding of and support for the decision and reduce the potential for conflict.

The actions required to implement this option fall well within the existing authorities of the agencies involved (i.e., Legislature, California Department of Education, Office of the State Architect, CPUC, and the California Department of Health Services). Little or no additional funding would be needed. Overall risk management in schools may improve if the attention and resources previously devoted to the EMF issue are freed up to deal with other risks to children and staff.

5.1.2 Option 2: Status Quo - Continue existing programs

The Status Quo option would continue existing EMF programs and policies. This policy is relevant under risk scenario #3 in which the current state of uncertainty about EMF risks persists. As Table 5.1 indicates, this option applies to all four decision settings. It could be elected either intentionally or simply by inaction.

The existing situation is characterized by a variety of structured and ad hoc policies, programs, and decision making about EMFs in schools. These are described in detail in Sections 4.2 - 4.5. The Schools

Facilities Planning Division of the Department of Education implements the *State School Site Selection and Approval Guide* (school siting guidelines). While these are based on electric, rather than magnetic, fields, they are an accepted part of the current management and regulatory system. However, they could be modified to deal with magnetic instead of electrical field levels. CPUC decision 93-11-013 required investor-owned utilities to provide measurements upon request, free of charge, at residences and workplaces. Workplace has been interpreted to include schools and some schools have taken advantage of this service. In addition, there is widespread use of low-cost, no-cost field reduction measures in new utility construction, in accord with the provision of CPUC decision 93-11-013 to spend up to 4% of new project costs on reducing EMF fields. In deciding where to target these funds, hospitals, schools, and residential neighborhoods were given first priority in the EMF design guidelines developed by each utility. Further, several research projects have been completed that focus exclusively on schools:

- a drive-by survey of school proximity to electric power lines
- development of a decision analysis framework for evaluating policy alternatives (this project)
- exposure assessment to study sources of EMF exposure in public schools (Enertech project)
- research on minimizing EMF in school design which resulted in the publication *EMF Checklist for School Buildings and Grounds Construction* (funded through the national EMF RAPID program).

Apart from these activities, few efforts of the California EMF Research and Information Program, CPUC decisions regarding EMF, and utility and other programs, have targeted the needs of schools in a consistent way and on a statewide basis. One notable exception is a utility that contacted all school districts in its service area to make them aware of the availability of utility EMF measurements and information. An advisory on siting portable classrooms on school campuses has also been distributed by the Department of Health Services. Finally, a handful of individual schools have received sometimes extensive assistance from the CDHS and utility staff in dealing with unique situations, some involving apparent clusters of health problems.

There are some elements of statewide consistency in the status quo. Most utilities provide school survey measurements, there is a set of uniform siting guidelines for new schools, and there is widespread consideration of low cost measures to reduce EMF in new construction. However, the siting guidelines apply only to new school construction and utility surveys typically do not furnish the detailed assessment data needed to design and implement effective mitigation strategies. Representatives of individual school districts have described the difficulty in obtaining adequate background information about the EMF issue and potential mitigation strategies and have identified the lack of authoritative guidance as an obstacle to decision making. Thus, particularly for those decision settings involving existing schools, the status quo is characterized by large variability in treatment of potential health risks from EMF in schools across the state. In some cases, conflicts originating from concerns about health have resulted in detailed analysis, actions to minimize exposure, and/or litigation. In other cases, EMF exposure in schools has been a low-priority issue with the result that little is known in these instances about EMF sources and exposure.

The Status Quo option specifically includes important components of a wait and see strategy, all based on the acknowledgement that current policies might need modification as more information becomes available. The interim CPUC Decision 93-11-013 set policy regarding new facilities but held existing facilities under advisement, without specifying a policy to deal with them. By keeping this issue open, the CPUC was in effect adopting a wait and see approach to this issue. In addition, decision 93-11-013 (Section 5.4.2) puts in place a key part of a wait and see strategy by identifying the California Department of Health Services as the agency responsible for performing and monitoring research, interpreting findings, and disseminating information to stakeholders.

By definition, the Status Quo option depends on existing authorities and sources of funding. It is not, however, a static situation because improved information being developed by the EMF Research Program about exposures in schools and about the costs and benefits of mitigation and other options have the potential for improving the cost effectiveness of exposure reduction efforts.

5.1.3 Option 3: Prohibit increases in EMF exposures from power lines near schools

Under this option utilities would be prohibited from increasing average and/or peak current loading on existing transmission and distribution lines within a certain distance of existing schools. Alternatively, utilities could be required to modify existing lines to keep magnetic fields on school grounds below historic levels, regardless of line loading. This policy would apply only to existing lines and substations and to upgrades along existing corridors. It falls under risk scenarios #2, "Hazard Identified but Dose-Response not Understood," and #3, "Present Uncertainty Persists." Because of the complexities of distribution networks, magnetic fields from distribution lines are more difficult to model and predict than magnetic fields from transmission lines. Therefore, it might not be practical to include distribution lines in this policy. Further study of this issue would be needed if this policy option were to be seriously considered.

Prohibiting increases in current loading and/or magnetic field levels depends on the ability to define historic baseline levels, for example, averaging over the most recent three to five years or over a period of years prior to a specific date. For now, a policy based on magnetic field limits is infeasible because there are not adequate data to characterize historic field values at schools near transmission lines and substations. Often there are better data available for historic current loads on transmission lines that could be used to set limits on a line-by-line basis. In the event that historic data are not a practical option, there are three workable alternatives. First, measurements could be made to establish baseline current loads and/or magnetic field strengths from recent operating conditions. Alternatively, baseline levels could be based on some fraction of rated capacity for each type of line and substation. A third approach would be to combine both solutions by implementing limits based on the rated capacity while collecting baseline data. This policy is analogous to regulations in other environmental arenas, particularly water quality, that prohibit any worsening from existing conditions, irrespective of whether or not these conditions exceed compliance standards.

In response to concerns about the potential health impacts of EMFs, Florida's Department of Environmental Protection instituted in 1996 a policy prohibiting increases in field strength for new and modified transmission lines and substations rated at 69 kV or greater. The central purpose of this policy was to prohibit "any new or modified transmission line or substation, under normal conditions, to cause electric or magnetic field strengths greater than the highest operating voltage and the maximum current rating (MCR) values for existing transmission lines and substations." The Florida policy differs in scope from the one described here. It applies to all power lines and facilities greater than 69kV, not just those near schools. In addition, the Florida policy is limited only to new and modified lines and facilities, specifically excluding those on which construction commenced on or prior to March 21, 1989. Nevertheless, the implementation procedures of the Florida policy illustrate those required for a limits-based policy, particularly one based on the theoretical capacity of each line or substation.

Florida set maximum electric and magnetic field strengths at the edge of the right of way for different sized transmission lines and substations. These maximum allowable electric and magnetic fields were based on models that took into account line current, line configuration, and local topography. The limits were not based on epidemiologic data or dose-response calculations.

The Florida policy specified in detail some features typical of environmental regulations. There was specific mention of the techniques by which field strengths would be estimated from maximum current rating and line configuration. The policy defined "right of way" in detail for a variety of typical circumstances. For monitoring purposes, it specified that devices for measuring and recording voltage and current flow or their equivalent are to be included on all new 230 kV lines or their equivalent and exceedances (as specifically defined) must be reported to the Department. Rather than monitoring electric and magnetic fields directly, this policy depends on well-established calculations that relate voltage and current flow to electric and magnetic fields at the edge of the right of way. Allowance was made for emergency situations in which the limits may be exceeded and an upper limit was set for the number of hours per year that such exceedances can occur. Additional exemptions could provide for proposed changes to power lines that could result in a large enough field reductions to allow for increasing current.

However, the Florida policy differs from the one proposed here in that its field limits are applicable to all lines within a particular category and are established near the maximum capacity of the existing lines. Thus the Florida policy does not prohibit increases on lines that are being operated below the maximum limit. In contrast, the policy option described here would require establishing a limit for each particular line based on its historical loading, independent of that loading's relationship with the capacity of the line or that of other similar lines. This will limit flexibility and, as discussed in the following paragraph, may require the construction of additional capacity elsewhere.

Because a policy prohibiting increases in EMF exposure would affect only line routes very near schools, an unintended impact might be encouragement of new power lines in other areas to accommodate needed load growth. The extent to which this might occur depends on spatial and temporal patterns in the growth of electricity demand and the degree to which this demand could be accommodated by switching loads from one part of the transmission or distribution network to another. For example, if lines near schools are being used at much less than their rated capacity, and if the limits reflect historic (rather than theoretical maximum) usage, then such limits might cause new lines to be built in other areas. A further consideration is that if lines in other areas are not being used at their rated capacity, loads could be switched to these other areas, thereby increasing magnetic field levels in that part of the community. However, utility engineers have a variety of techniques that permit increasing loads on existing lines without increasing magnetic field levels. These could be applied to lines near schools as well as to those in other areas. The impact on EMF levels near the lines may vary depending on whether the limit is framed as a magnetic field limit or a current load limit. Thus, the actual degree to which this policy option would constrain the delivery of electricity to areas of increased demand is highly variable and dependent on several context-dependent factors. Despite the possibility of switching loads to accommodate a limit near schools, from a practical standpoint, attempting to control loads on a lengthy power line to address exposures along a very short segment of that line near a school does not appear reasonable.

In addition, a larger issue is that the factors leading to increased currents on utility facilities are outside the control of utilities. Instead, they are in the control of cities and counties that approve new development and industry and consumers who may increase their electricity use.

Developing and implementing standards under this option would involve the activities outlined in Table 5.2.

Table 5.2. Steps involved in prohibiting increases in load/exposure for power lines and substations near schools.

Major Steps	Specific Actions
I. Definitions and rulemaking	a. Define affected schools and power lines
	b. Define average current load
	c. Adopt protocol for measuring average current load
	d. Define location and level of "not to exceed" electric/magnetic fields
	e. Define exemptions for emergencies, field reduction methods
II. Compliance	a. Define exceedences of average current load
	b. Define compliance options
	c. Define time allowance for compliance
III. Enforcement	a. Adopt protocol for determining violations of average current load limits
	b. Establish penalty for violations
IV. Gather baseline data	a. Identify all power lines of interest
	b. Determine average current load for these lines
	c. Register applicable lines and average current with implementing agency
	d. Verify average current load ratings
V. Surveying and reporting	a. Monitor actual average current load
	b. Periodically monitor electric and magnetic fields at defined location
	c. Submit reports to implementing agency
	d. Provide copies of reports to school administrator at affected school

5.1.4 Option 4: Field-strength standards

This policy may apply to power lines (new and/or existing) and/or building sources. It might be adopted as a prudent policy pending a definitive conclusion on the presence and extent of EMF health risks (risk scenario #3, present uncertainty persists). It could also be adopted as a response to such definitive information if and when it becomes available (risk scenarios #1 and #2, hazard identified). Of course, the scientific basis for standard setting would be clearest under risk scenario #1, dose response understood, less clear under scenario #2, dose response not understood, and least clear under scenario #3.

Developing and implementing standards under this option would involve the activities outlined in Table 5.3. The number of situations affected by the policy would depend on the field level chosen for the standard, whether the standard is applied to new and/or existing schools and power lines, and whether the standard applies to power line fields and/to fields from building wiring or appliances.

Because magnetic fields vary in space and time, any field standard must specify how this variation shall be taken into account. It is extremely difficult and expensive to measure school fields continuously and in all locations. The challenge is to design a practical and affordable protocol that is nonetheless able to detect most exposure situations of concern. There are a number of options. Which is chosen should depend on survey budgets, and on policy makers' tolerance for false positives (finding a high field situation when there is none) and false negatives (failing to find high fields when they are present). Field-strength standards that depend on spot measurements, while they miss the temporal variation in fields, are much easier and cheaper to administer than are field-strength standards that incorporate temporal variation. Thus, there is a tradeoff between simplicity of implementation and the inefficiencies associated with ignoring temporal variation.

Specification of standards using "never-to-be-exceeded" field strengths is impractical because the measurements needed to support such a standard would be too costly. A more practical standard might specify a particular density of spot measurements (e.g. 2 meter grid) to be taken during school hours and then corrected for season and time-of-day using universal correction factors derived from the Enertech database for schools and additional focused sampling. The standard could be specified for one or more of the following: school-wide spatial average field level, spatial average not to be exceeded in any regularly occupied area (e.g. classroom, library), and spatial maximum field (defined as some percentile of the spot measurements) not to be exceeded in any regularly occupied area. If short-duration exposures to high field levels are a concern, the standard might also specify maximum fields in areas occupied only occasionally (e.g. hallways, bathrooms).

Table 5.3. Steps involved in setting and implementing standards based on field strengths for EMF exposures in schools.

Major Steps	Specific Actions
I. Definitions and rulemaking	a. Define affected schools and power lines
	b. Specify maximum average magnetic field limits, including averaging time, place of measurement, field value, areas included or excluded Or:
	Specify ceiling values, including place of measurement, field value, areas included or excluded
	c. Adopt protocol for measuring fields, including spatial and temporal qualities and allowable exceedences, if any
II. Compliance	a. Define compliance options for existing facilities: relocating, reconfiguring, abandoning, shifting load, or undergrounding power lines; physical changes to school facilities such as rewiring, replacement of equipment; changing use patterns of school buildings, rooms, and grounds
	b. Specify EMF design standards for new schools
	c. Define time allowance for compliance
III. Enforcement	a. Adopt rules and protocol for determining violations, notification, publication
	b. Establish penalty for violations
IV. Gather baseline data	a. Survey schools
	b. Identify non-complying schools
	c. Identify power lines associated with non-compliant nearby schools
	d. Measure existing magnetic fields for power lines
	e. Calculate future maximum average fields based on design load
	f. Register power lines information (location, average, and future maximum magnetic fields) with implementing agency
	g. Process permanent or temporary exclusion for power lines that meet standard (temporary exclusion to apply where standards are met at current load, but where standards might be exceeded under the existing configuration if loads are increased)
V. Surveying and reporting	a. Periodically conduct surveys and report magnetic fields for schools and power lines near schools
	b. Submit reports to implementing agency
	c. Provide copies of power line reports to school administrator at affected school

Field-strength standards would need to differentiate between fields from operator sources (e.g. computers, electric pencil sharpeners) and fields from area sources (e.g. power lines, net currents). Methods for assessing exposures for these two types of sources differ greatly, so field-strength standards would have to consider each type separately. Standards for operator sources might specify maximum field strength profiles to be applied to purchases of new equipment. Standards for operator sources might specify that no student shall be seated within a certain distance of operator sources being operated by others.

For a field standard option, various rules may be applied to different areas of the school grounds based on whether they are occupied continuously or sporadically. For example, hallways, storage areas, rest rooms, locker rooms could be exempted. Areas of existing school grounds that exceed the standards would require physical modifications such as rewiring or remodeling, or changes in activity patterns such as changing the use of an area, to bring them into compliance. Low field design guidelines could be adopted for new schools to minimize internal sources, and existing school siting guidelines would continue to be implemented.

As an alternative to numerical field standards for power lines, some propose using “wire codes” to place limits on the configuration of power lines near schools or on the proximity of school areas to those lines. As discussed in detail in Section 2.3, this approach is unlikely to be better than managing magnetic field exposure based on field strength *per se*. Therefore, we do not consider wire codes as a possible basis for regulation of EMF fields in schools.

5.1.5 Option 5: Maximum permissible time-averaged personal EMF exposure standard

The time-averaged exposure limits in this option differ from field strength based standards in that people’s activity patterns are taken into account. If risk is believed to be cumulative, so that long exposures to low fields carry the same risk as short exposures to high fields, then a personal exposure standard could have some efficiency benefits over a field strength standard. For instance, high schools that have a few classrooms with high field strengths may not have to reduce these field levels, since high school students change classrooms from hour to hour. Their total exposure over the course of the school day will not be influenced greatly by spending just one hour in a classroom with elevated field levels. This may not be the case for teachers, however, who typically spend more of their day in just one classroom.

This policy would have to specify an averaging period for exposure. One possibility would be to specify the averaging period based on a typical school day with the requirement that a school-day time weighted average (TWA) not exceed the median California home TWA. Other possibilities would be shorter or longer averaging periods, and perhaps different field limits.

There are many possible ways to implement this policy. One would be to map fields in all school facilities and estimate the time spent in each area by each student and staff. Daily personal exposure estimates could then be made for each student and staff. Mitigation options could then be considered only for those individuals whose daily exposure exceeds the standard. The cheapest set of mitigation options needed to bring everyone's personal exposure into compliance would be the set adopted. These mitigation options might include either reducing field strengths or changing where particular individuals spend their time.

The added complexities of this policy over a field strength limit may be justified by the savings in mitigation costs. No estimate of the amount of these savings is currently available, but they would vary considerably from school to school. One disadvantage of the personal exposure compared to field strength limits is that the former would be less efficient than the latter in the event that dose-response relationships are not linear. For instance, personal exposure limits based on TWA exposure would not be advantageous in the event that EMF risk accrued only above some threshold field strength.

5.1.6 Option 6: Technology-based standards

Technology-based standards could apply to both power lines and building sources, and to both existing and new power lines and schools. This option differs from others that involve setting standards for EMF levels and/or exposures in that it defines the control measure (technological fix) rather than the outcome (EMF level/exposure). In the more traditional approach to implementing technology standards, all facilities would comply with the same standards regardless of actual exposure levels in the schools. A more flexible policy would make the implementation of alternate technology "fixes" conditional on load and/or field levels in each specific circumstance. This policy would require future monitoring of facilities to ensure compliance with standards.

Technology standards that might be applied to EMF in schools include the following:

- Configuration, set-back, and line-height standards for distribution and transmission lines near schools.
- Requirements for net-current warning lights on individual circuits leaving electrical panels.
- Requirements for electronic ballasts in fluorescent lighting fixtures.
- Requirements that power transformers and electrical panels be placed at some minimum distance from any continuously occupied area.

In a sense, the National Electrical Code requirements for connection of neutral and ground wires is a technology standard. This might be added to the above list as a measure for preventing magnetic fields from net currents.

There is a long history of technology-based standards in other areas of environmental concern (e.g., air and water quality, automobile safety). Such standards ensure that all relevant facilities are complying with at least a minimum level of environmental or health and safety protection. They are also fair in the sense of imposing the same costs on all facilities. Another benefit of technology standards is their simplicity. No magnetic field surveys and source identification are needed. On the other hand, there is abundant evidence that technological standards are less economically efficient than alternatives that focus on aspects of either ambient pollutant (field) levels or actual human exposure. Schools that would not have to perform any field reduction under a field-strength standard, might still be required to invest in mitigation under a technology standard.

At present, most large electric utilities in California have adopted EMF Design Guidelines for new facilities as a result of CPUC Decision 93-11-013. These guidelines compare different methods for reducing EMF in the construction of new distribution and transmission lines and substations. They are intended for use by utility personnel who are involved in the planning, design, construction, and reconstruction of electric facilities. Technology based standards for schools would require comparable guidelines to be developed and adopted for schools for use by planners, architects, and engineers involved in the design and construction of both new and remodeled schools and power lines near schools. As in the CPUC policy, low-cost standards could be established for risk scenario #3, present uncertainty persists, and higher-cost standards considered if and when information about EMF hazard becomes clearer (risk scenarios #1 and #2).

With funding from the national EMF RAPID Program, CDHS recently completed the *EMF Checklist for School Buildings and Grounds Construction(CALIF_DHS, 1999)*. The checklist incorporates the state school siting guidelines regarding power lines and identifies no-cost and low-cost field management techniques for use in site planning, building design, construction, occupancy, and remodeling. The checklist could be the basis for mandatory statewide technical standards appropriate to risk scenario #3, present uncertainty persists.

Any technology-based standards applied to school would be implemented by the California Department of Education and the Office of the State Architect under their existing authority to establish standards for school construction.

5.1.7 Option 7: Enforce relevant provisions of the National Electrical Code

The Enertech study of exposure in California schools (Zaffanella and Hooper, 2000) found that a major source of EMF exposure is improper electrical connections in wall wiring, both between neutrals and between neutral and ground. The National Electrical Code (NEC) prohibits paralleled neutral conductors in a circuit, and neutral-to-ground connections must be made only at the service entrance point. In California, there is no mechanism for ensuring that schools comply with the NEC. In fact, school districts are not required to have new schools inspected by local building inspectors; they perform their own inspections. Under this policy, new schools would be required to specify that the electrical contractor perform appropriate tests on all circuits and fix any improper connections. The equivalent of "low field design guidelines" would be developed for new schools that would include this and other accepted practices for keeping internal source exposure to a minimum.

Existing schools would be required to obtain an electrical inspection to check for improper neutral connections, and to correct these conditions. Correcting such wiring errors will not only reduce magnetic field levels but will also reduce the risk of electric shock, electrical fires, and overvoltage damage to electrical and electronic equipment. At this time, we are unable to quantify the size of these co-benefits because the incidence of electrical shock, fire, and equipment damage in schools is unknown.

The relevant provisions of the NEC were described in an April 28, 2000 letter from the School Facilities Planning Division to all school districts in California. They include:

- Section 250-24(a)(5) – 1999, prohibiting connection of neutrals to any grounding connection on the load side of the service entrance main disconnect. This was formerly Section 250-61(b).
- Section 310-4, prohibiting connection of a neutral to another neutral such that a parallel return path to the panel is set up, unless the conductors are 1/0 or larger and meet exacting conditions.
- Section 300-3(b), requiring all conductors of a circuit to run together in whatever channel they are using. This reinforces article 310-4.
- Section 300-20(a), which repeats the above requirement with attention to circuits running in metallic enclosures such as conduits, point out the inductive heating effect on the conduit.
- Section 250-32(b) – 1999, which no longer allows the neutral bus in the panel for a separate building to be bonded to the ground at the panel unless there are no grounded metallic connections between the buildings. This replaces former Section 250-24(a).

The National Electrical Code is constantly being updated, so some of these provisions may not have been in force at the time that a school building was constructed.

5.1.8 Option 8: Statewide program to address all health and safety risks in schools

This option differs greatly from the others considered here in that it requires coordinating a much broader range of risk prevention efforts compared to those that only consider possible risks from EMF exposure. The underlying motivation is to allocate society's limited resources for reducing risks in schools where they would achieve the greatest overall risk reductions.

A risk-based standard for schools would require that schools address their worst risks first (or their most efficiently mitigated risk first), whether or not they are related to EMF. Non-EMF risks involve both injury and illness and this option would require a statewide assessment of risk statistics to establish priorities for risk reduction. This option could be implemented in one of two ways. The first approach would use national or statewide statistics to identify and prioritize risks, which would then be addressed uniformly in all schools throughout the state. The second approach would require individual school districts to follow statewide guidelines to prepare district-wide risk assessments a broad range of risks. Site-specific checklists could then help identify schools with the most significant problems based upon criteria established in the guidelines.

5.2 Analysis of exposure and risk reduction options

The options described above differ substantially across a range of factors important to decision makers, including:

- potential for exposure reduction
- costs
- implications for equity, fairness, and environmental justice
- implications for liability and potential litigation
- administrative effort
- adaptability to future changes in knowledge.

This section compares the exposure and risk reduction options from the perspective of each of these key factors.

5.2.1 Potential for exposure reduction

At one extreme, eliminating existing EMF programs will obviously not result in any exposure reduction. For the remaining options, the results of the Enertech of California schools (Zaffanella and Hooper, 2000) helps provide a basis for ranking the options in terms of their potential for exposure reduction. For the status quo option, the improved information about sources of exposure in schools and about the costs and benefits of mitigation and other options has the potential for improving the effectiveness of existing exposure reduction efforts. However, the statewide impact of this improvement will probably be low, since exposure reduction efforts would remain largely at the discretion of decision makers in the 800 local school districts. Prohibiting increases in fields around existing power lines will have little impact on exposures in schools, given that the majority of elevated fields are due to internal sources. There is some chance that, over the long run, this option could have community-wide impacts if additional capacity needed to be constructed elsewhere to compensate for the loss in growth potential on existing lines near schools. Under some scenarios, the consequences of such a policy might be a net increase in population EMF exposure from the transmission and distribution network as a whole. The exposure reduction potential for options to set field or personal standards depends entirely on the level at which standards are set. In theory, these options have the potential for substantial exposure reduction, assuming standards are set at a low level. Enforcing the electrical code within classroom buildings has the greatest potential for reducing exposure because this would directly address the most important source of elevated fields in schools.

5.2.2 Costs

The costs of possible EMF management policies can have any or all of the following components:

- Administrative costs for the implementing agency to both promulgate and enforce the policy
- Administrative costs for schools and other organizations to interpret and implement the policy
- Information gathering costs, often paid to consultants, for surveys, analysis, and design.
- Capital or construction costs to effect any needed changes in electrical system design or hardware.
- Ongoing space usage costs, for cases in which the space has been allocated to a lower-valued use.

Observations on the cost components of particular policy options are as follows.

5.2.2.1 Costs of the Status quo

Under the status quo, EMF problems in schools are handled on a case-by-case basis. On the one hand, statewide costs under the status quo have been relatively small, because few schools with elevated EMF levels have actually placed EMF risks on their management agenda. On the other hand, the case-specific costs to proceed on case-by-case basis are quite high. Each school that encounters an EMF problem confronts a steep learning curve and weeks of rancor as school officials, parents, and perhaps the local utility debate options. Expensive consultants often must be hired at school expense to provide information on field levels, sources, and mitigation options. If it is decided to reduce exposures in some area of the school, these reductions are usually performed at school expense. Thus, wealthy school districts are more likely to attend to EMF problems than poor districts.

Most utilities will provide free spot measurements of magnetic fields within schools, from all sources. But detailed surveys and further technical assistance are not standard services available from all utilities. Consultants are not in a position to determine cost or feasibility of field reduction actions on the utility system without substantial input from the utility. Ultimately, the utility must approve or disapprove of any proposed changes to their facilities and cost sharing is rarely negotiated. In addition, the frequent reluctance of involved parties (e.g., school administrators, utilities, consultants, public health officials) to rely on information provided by each other can dramatically drive up the cost of responding to parent and staff concerns about EMF.

5.2.2.2 Costs of prohibiting increased exposure from existing lines

The costs of this option would differ for transmission and distribution lines. Assuring that magnetic fields from an existing line do not exceed historical levels would require (i) monitoring of field strength both to establish what the historical levels and to check for future compliance, and (ii) modifying the power system to maintain historical field levels, should magnetic field levels start to increase. Those modifications can take the form of either load limits or changes to the line configuration. The costs of load limits include those associated with the additional hardware needed to control load, the stranded costs of the line capacity that goes unused, and the costs of additional capacity that must be built elsewhere to compensate for the load restriction. Note that this additional capacity will create additional magnetic field exposure. The hardware costs to limiting loads will differ for transmission and distribution lines. We have not estimated such costs. The costs of modifying transmission and distribution lines to maintain historical ground-level fields on school grounds range from a few thousand dollars for simple changes to distribution lines to a few million dollars for major modifications to transmission lines.

5.2.2.3 Costs of magnetic field standards

The costs of this option are detailed in the EMF_SCHOOL computer model and its documentation (Florig, 2000), as well as in Enertech's report (Zaffanella and Hooper, 2000). These costs include

- Survey costs to identify areas that are out of compliance and the sources that produce those fields
- Engineering analysis costs to identify the most cost-effective technical or space-usage option to reach compliance with the standard.
- Capital and construction costs to implement the most cost-effective measures to reach compliance.
- Space usage costs for cases in which field-strength standards are met by abandoning the space that is out of compliance.

These costs differ considerably by type of source. As shown in Figure 6.4, electrical panels have the largest total costs. Although each case of a net current problem is inexpensive to fix, net currents are the most common cause of elevated magnetic field levels, so total costs are high. Electrical panels have the second highest cost for field strength standards above 3 mG, largely because there are relatively few cases on which to spread survey costs. Transmission lines are also expensive to fix, but there are relatively few cases of transmission line problems compared to problems from other sources. Overall, if Enertech's unit cost estimates are taken at face value, the statewide costs to implement a 2 mG spatial average in all classrooms would be about $80 million. Transmission line costs would comprise only about $15 million of this amount. Estimates of the cost-effectiveness of field-strength standards, described in Section 6.7.5, show that modifications to net currents and distribution lines have much lower costs per unit of population exposure reduction than do modifications to electrical panels and transmission lines.

5.2.2.4 Cost of personal exposure standards

Of all the policy options considered here, personal exposure standards can produce the greatest population exposure reductions per unit engineering expenditure (i.e., costs of modifying internal sources and power lines). This is because the regulatory target is exposure itself and not some surrogate such as field strength or technology type. With personal exposure limits, no money is wasted reducing field strengths in areas where people spend little time. Personal exposure limits might be satisfied at very low cost in some cases, simply by rotating where children sit within a classroom. Such an option would not be admissible under a field strength or a technology standard. Although the engineering costs per unit risk reduction are low for personal exposure standards, the administrative costs for personal exposure standards are high. This is because the exposure for each student and staff member has to be individually assessed, modified, and monitored. The high administrative costs for personal exposure standards often outweigh savings in the engineering costs of mitigation. Currently, ionizing radiation is the only hazard that is managed with personal exposure standards, and then only for occupational environments in which it is easy to use personal dosimeters.

5.2.2.5 Cost of technology standards

For a given expenditure in exposure reduction, technology standards will yield lower exposure reductions than either field-strength standards or personal exposure standards. This is because technologies would be applied uniformly, without regard to existing field levels or occupancy rates. Although technology standards would involve no expenses for EMF surveys and source identification, these expenses are generally small compared to the cost of mitigation itself. The costs of administering a technology standard would be expected to be lower than administration costs for either field strength or personal exposure standards (for the same degree of risk reduction), simply because less information is needed to apply and enforce technology standards. One need only assure that a given structure is in place, without having to measure any fields.

5.2.2.6 Cost to enforce provisions of the National Electrical Code

For existing schools, the costs to enforce relevant provisions of the National Electrical Code would be the same as the costs to find and repair existing net current sources. If Enertech's unit costs to find and repair a net current source are taken at face value, the statewide costs to survey and repair all net current sources producing more than 0.5 mG average field in any one classroom would be in the neighborhood of \$75 million. This is an average of roughly \$10,000 per school. Costs for new schools would be less, because electricians can more easily access building wiring at the time of construction than after the building is occupied. Also, older buildings may have many undocumented circuits that make it more difficult for an electrician to isolate the cause of the net current problem. These costs do not include any administrative costs incurred by the school to learn about the problem, hire contractors, etc..

5.2.2.7 Costs to address all school risks

In Section 2.4, we note that the most significant non-EMF mortality risks in schools are commuting to school, non-sports accidents at schools, infectious diseases, sports teams, and intentional injury. If EMF is truly a cause of leukemia, then EMF mortality risks for those chronically exposed to fields of 3 mG and above would fall within in the range of these most common risks. Whereas reducing EMF exposure has certain costs, but uncertain benefits, reducing non-EMF hazards at schools offers assurances that student/staff risks will actually be reduced. While we are aware of no studies of the costs of non-EMF risk reduction in schools, there may be hundreds of measures that might be used to reduce non-EMF risks in schools at low or no cost. Further consideration of this option would require research to compile a list of these options and to estimate their cost-effectiveness.

5.2.3 Implications for equity, fairness, and environmental justice

Stakeholders evaluate the desirability of alternative policies, not only in terms of both their quantitative (e.g., exposure reduction, cost) and qualitative (e.g., minimize worry, maintain quality of education) attributes, but also from the standpoint of how fair or just the results of these policies may be. Definitions of "fairness," "justice," and "equity" vary from author to author and the literature in this area often uses these terms interchangeably (Lence et al., 1997; Paterson and Andrews, 1995; Young, 1993). We will use the single term "fairness" to refer also to the associated concepts of "justice" and "equity." Social scientists find that equity issues are often central to many environmental policy disputes, yet equity issues are rarely treated explicitly in the policy making process. Ignoring the resulting undercurrents makes it more difficult for decision makers to understand stakeholder positions, and can lead to unnecessary rancor. We therefore raise these issues explicitly in this report.

We identify two primary categories of fairness, distributive and procedural. Distributive fairness refers to the ultimate distribution of costs, exposure reduction, and other impacts/benefits, regardless of how policies were decided upon. For example, an equitable overall outcome for an exposure reduction policy might be one in which residual EMF population risks are more equally distributed across schools and residual individual EMF risks are more equal within a given school. Procedural fairness refers to the decision-making process involved in choosing among options and includes issues such as whether everyone affected by a decision has been involved in decision making, whether they have had equal and adequate access to needed information, and the degree to which the final decision is based on consensus among the involved parties. For example, an equitable procedure for arriving at this outcome might be one in which schools are prioritized for mitigation based on a lottery that treated all schools equally. Procedural fairness can be more important than distributive fairness, given stakeholders' documented willingness at times to accept a less efficient or less advantageous distribution of outcomes if these have been chosen in ways perceived to be fair to all. Section 5.5, which deals with implementation of policy options, returns to the issue of procedural fairness.

We identify six more criteria of fairness that are useful in evaluating and comparing alternative policies. These criteria are divided into the utilitarian and ethical approaches to decision making described in Section 3 and can be defined as follows (Paterson and Andrews, 1995; Young, 1993):

- *aggregate welfare* - distribute costs and benefits to maximize the resulting aggregate welfare of society (cf. Bentham's utilitarianism)
- *contribution* - distribute costs and benefits in proportion to individuals' or groups' contributions to them (cf. Aristotelian ethics, libertarianism, other rights-based principles)
- *need* - redistribute costs and benefits in proportion to need (egalitarianism of outcomes, not merely of rights and opportunities)
- *compensation* - redistribute costs and benefits to compensate those who are either worst off in general or most disadvantaged by a particular policy outcome (Rawls' maximin principle)
- *equality* - impartial, even-handed dealing in which all are treated without distinctions or preference
- *acceptable* - outcomes that are accepted by all as fair or "envy free."

Environmental justice is a subset of broader fairness concerns. It refers specifically to attempts to address the fact and/or the potential of disproportionate exposure of minority populations to pollutants and other environmental risks. The principles of environmental justice mandate that in situations where impacts unjustly or unequally fall upon minority populations, those populations be provided better access to decisions, compensated more fairly for costs and impacts, and that a priority be placed on pollution prevention efforts that will reduce disproportionate impacts on those minority communities (Bullard, 1990; Foreman, 1998). Environmental justice includes several types of fairness, including contribution, equality, and acceptance. The concept of contribution fairness underlies the goal of avoiding exposures that are out of proportion to minority communities' use of or benefit from potentially toxic activities. Equality fairness underlies the desire that minority communities be treated equally with other parts of society and acceptance fairness underlies the premise that minority communities should have the right to accept or refuse the siting of potentially harmful activities. Finally, the emphasis on full and open access to decision-making processes reflects the importance of procedural fairness in environmental justice.

Our analysis here treats both outcome and process features of alternative policy options. However, as the following paragraphs make clear, a great deal of any judgment about the equity, fairness, or environmental justice implications of policies depends on the specific way(s) in which they are implemented, not on the options themselves (see Section 5.5).

Option 1: Eliminate existing EMF programs. From the perspective of most kinds of fairness, there should be no particular fairness impacts associated with this option, assuming that the basis for the decision is communicated effectively to all concerned parties. However, depending on the process through which the decision to eliminate existing programs was arrived at, certain stakeholders may believe that procedural fairness has been violated and may consequently find the decision unacceptable. A perception that the decision is unfair may raise administrative effort and costs, as additional concerns and challenges must be responded to. In addition, to the extent that there are costs involved in unwinding ongoing programs, the way in which these costs are funded may raise need fairness concerns if school districts are expected to pay such costs regardless of their relative wealth.

Option 2: Status Quo- Continue existing programs. The diversity of actions and programs that make up the status quo (Section 5.1.2) gives rise to an equivalent range of fairness impacts. At present, the burden of responding to specific parental and staff concerns falls primarily upon the shoulders of local school administrators. To the extent that EMF exposures and resultant concerns stem from transmission lines, substations, and other electrical infrastructure, then this violates the principle of contribution fairness, since schools have not contributed directly to this source of exposure. However, if, as the Enertech survey suggests, the bulk of EMF exposure in most schools stems from internal sources, then the status quo would not violate this fairness criterion. The status quo is also characterized by a wide disparity among school districts in the resources (time, money, expertise) they have available for the EMF issue, for both decision making as well as for actual mitigation, a violation of the principle of need fairness and also possibly of the aggregate welfare criterion. The former violation stems from poorer school districts having less resources than they may need and the latter from the possibility that marginal dollars spent on this issue may produce greater benefits in poorer than in richer districts. The Enertech survey (Figure 8.34 in Zaffanella and Hooper 2000) showed that median classroom fields for schools in the lowest SES category are about 0.25 mG higher than the median field for all other SES categories combined. Given that the marginal cost of control increases with decreasing field strength, the most cost-effective opportunities for exposure reduction will be found at low SES schools. Despite these fairness impacts, an important feature of the status quo is that schools and communities have wide latitude to deal with EMF in a way that is consistent with local situations, concerns, preferences, and resource availability, latitude that may contribute to procedural fairness and the acceptance of solutions arrived at locally.

Another aspect of the status quo is a series of survey, research, information dissemination, and policy development programs whose products will reduce inequities stemming from differences in school districts' resources for responding to concerns about EMF exposures. Since the research program is developed and reviewed with the direct involvement of a Stakeholders Advisory Consultants, it meets the equality and acceptance fairness criteria for implementing policy. In addition, the school siting guidelines treat all schools equally in accord with the equality fairness criterion.

Yet another feature of the status quo is an explicit wait and see component. The perceived fairness of this component, particularly in terms of aggregate welfare, is sensitive to one's belief about the likelihood that EMF exposure poses a material health risk, with presumed likelihood and perceived fairness inversely related. Given that the wait and see component is being carried out by the Department of Health Services and that its cost is relatively low, there are no fairness implications associated with funding.

Option 3: Prohibit increases in EMF exposures from transmission lines near schools. The fairness implications of this option are similar to those of the Status Quo option in that it would freeze the existing situation, with any embedded inequities. If existing transmission lines were disproportionately located near poor and/or minority schools, then freezing exposures would violate the equality fairness criterion. The Enertech survey results suggest that this is not the case, however. About half of all schools near transmission lines in the Enertech sample are in communities of low or middle-low socioeconomic status. This is no different from the sample of all 89 schools in the Enertech sample.

If this option caused increases in exposure along other lines in the transmission and distribution network (see Section 5.1.3), then it could violate the aggregate welfare and equality fairness criteria. If population densities along lines running near schools tend to be lower (greater) than population densities along alternative lines used to carry currents above the policy limit, and if magnetic field levels produced by power lines near schools are comparable to or lower (greater) than magnetic field levels produced by alternative lines, then this policy would increase (reduce) total EMF population exposures. This would violate the aggregate welfare criterion. The aggregate welfare criterion would also be violated to the extent that efforts to implement this policy impeded efforts to address more severe health risks in schools. It would also violate the equality fairness criterion because it would create differences in exposure. Unfortunately, we have no data that would allow us to compare population exposures and field profiles associated with power lines near and far from schools, so we have no way of estimating what the statewide change in total population exposure from this policy might be. Finally, this policy could violate the acceptance fairness criterion if portions of the population were exposed to increased fields without their knowledge and consent.

Option 4: Field standards for internal and external sources of EMF. In principle, this option treats all schools equally by setting equivalent performance standards, without regard for income level, minority status, or presence/absence of other sources of potential risk. Also in principle, it is neutral in terms of other kinds of fairness. However, important fairness implications will arise depending on how this option is implemented and funded (see also Section 5.4 on implementation). Standards may or may not contribute to aggregate welfare fairness depending on the mix and severity of other risks facing children and staff at each school (see option 5.1.9), and the amount of exposure reduction at each school and the cost of achieving it. A requirement to pay for expensive mitigation to reduce exposures that are only slightly above the standards will be perceived as unfair from a utilitarian perspective, irrespective of the source of funding. The costs for this option will vary more among schools than will costs for implementing technology standards. If it costs more to mitigate higher exposures, and if higher exposures occur disproportionately at poorer and/or minority schools, then this option could be perceived as violating several fairness criteria (need, compensation, equality) depending on how mitigation costs are funded. The perceived fairness of funding options will depend on the specific circumstances of each school (e.g., source(s) of elevated exposure, available resources) and the details of the funding options themselves (see Section 5.4 and Section 8 for more detail on funding options).

An implementation schedule that targeted the highest exposure schools first would meet the criterion for need fairness, and one that prioritized poorer districts would meet the criterion for compensation fairness (see Table 5.9 and related text for more detail on implementation pathways). Further, the time allowed to achieve compliance will influence the perceived equality fairness of this option, especially if the compliance schedule varies from school to school in ways that open the door to suspicions of favoritism or other unequal treatment. This and similar fairness impacts can be alleviated by careful attention to the elements of procedural fairness and the acceptance fairness criterion.

Option 5: Maximum permissible time-averaged personal EMF exposure standard. Because we judge this option to be administratively impractical, (see Section 5.2.2.3), we do not discuss its fairness implications.

Option 6: Technology-based standards. Technology-based standards have the virtue of imposing similar costs on all schools by requiring that all schools (or utilities) adopt the same control technology or technique, regardless of pre-existing exposure conditions. This "equal treatment" property, combined with its low administrative costs compared to many alternatives, led to technology-based standards being used successfully for many years for air pollution control. Although technology-based standards impose equal costs on all parties, they are less economically efficient than field-strength standards, and thus would not be favored by those with a utilitarian ethical world view.

Option 7: Enforce relevant provisions of National Electrical Code in all new/existing schools. The fairness implications of this option are virtually identical to those of establishing field standards for internal and external sources. The only substantial difference is that contribution fairness is much less of an issue for this option because it presumes that the issue of the relative contribution of internal and external (e.g., transmission lines) sources of elevated EMF exposure has already been resolved. If this were not the case, that is, if this option were enacted in the face of evidence that external sources of elevated EMF exposure were dominant or under continued uncertainty about the relative contributions of internal and external sources, then it would be perceived to have violated the contribution fairness criterion. The aggregate welfare criterion would also be violated to the extent that efforts to implement this policy impeded efforts to address more severe health risks in schools.

Option 8: Statewide program to address all health and safety risks in schools. This option focuses primarily on meeting the aggregate welfare fairness criterion. The degree to which it satisfies or violates other fairness criteria depends entirely on how risks are prioritized for mitigation and how mitigation actions are funded. Under this option, EMF risks may not be addressed, in favor of addressing larger, or more easily reduced risks (e.g. risks of commuting to school). If risk management priorities under this policy were set on a school-by-school rather than on a statewide basis, then fairness concerns regarding failure to address high-EMF schools would not be a problem. We note that a statewide policy to address EMF risks alone is likely to be criticized by utilitarians wishing to maximize aggregate school safety for a given expenditure.

5.2.4 Implications for liability and potential litigation

All the exposure and risk reduction options are well within the bounds of regulatory actions typically taken by the CPUC, CDE, and CDHS to address environmental, health, and safety issues. Thus, no new general authority would be required for enacting them, although specific findings, recommendations, and new regulations would be needed. We briefly review the statutory authority of the key agencies and discuss implementation issues specific to individual options, where relevant.

The CPUC has broad authority under Article XII, Section 6 of the state constitution to establish rules for utilities under its jurisdiction and related authority under Public Utilities Code Section 451, which requires regulated public utilities to operate in a manner that promotes the health and safety of its patrons, employees, and the public. The CDE also has broad general authority, under Section 33031 of the Education Code to oversee the "government of day and evening schools," which includes health and safety issues. The CDHS has similarly broad general authority, under the Health and Safety Code, to protect human health.

The CPUC, through its rule making process, can directly enact decisions that affect all regulated utilities in the state. As described in more detail in Section 4.3, the California Energy Commission can determine there is a need for new generating stations and the transmission lines to link them to the power grid, although the CPUC retains responsibility for siting and dealing with potential impacts of such transmission capacity. The CDE, which acts largely as the administrative agency of the State Board of Education, typically develops specific regulations through the steps defined in the Administrative Procedures Act. This was the process followed to include the school siting guidelines in Title 5 of the California Code of Regulations. Where there is a suitable mechanism, as in the need for site approval by CDE prior to the allocation of state funds for school construction, the CDE can enforce regulations such as the siting guidelines. However, the Department has little independent authority to enforce compliance with regulations. For example, schools sites financed with local funds are not subject to review by the CDE. In particular, health and safety issues relating to school children are left largely in the hands of local school boards. The CDHS acts primarily as an advisor to other state agencies. In rare instances, it can act directly when there are immediate threats to public health and safety. In the case of EMF, however, its primary roles, as described in CPUC Decision 93-11-013, would be to conduct research, synthesize and communicate information about health risks, and prepare recommendations about how to deal with these. CDHS is often active in developing legislation and regulations, sometimes independently and sometimes in cooperation with industry or public interest groups. As with the CDE, such efforts follow steps outlined in the Administrative Procedures Act.

Each of the three major agencies with roles to play in developing statewide policies for EMFs in schools thus has important authority as well as key constraints on that authority. The CPUC can enact rules but can enforce these only for regulated, not municipal, utilities. The CDE can adopt regulations that apply to all schools in the state but has little independent enforcement authority, particularly over schools that are financed with local, rather than state, funds. In addition, the CDE cannot always ensure that other agencies adopt in accord with its regulations, as illustrated by the fact that the CPUC does not always observe the CDE's siting guidelines when permitting new transmission facilities near existing schools. The CDHS is looked to by both the CPUC and the CDE to furnish scientific information about EMF and to make recommendations about what policies should be adopted. However, it has little capacity to enact such recommendations on its own authority, except in extreme cases that involve clear and present risk of morbidity and/or mortality to the public.

Table 5.4 summarizes the role each agency would play in enacting the exposure and risk reduction options. The specific actions needed to enact the Eliminate Programs and Status Quo options are described in Sections 5.1.1 and 5.1.2, respectively. The Prohibit Increases option would be enacted by the CPUC through its normal decision process. Enactment of the Field and Personal Standards is within the authority of the CDE. However, actually achieving these would require coordination with the CPUC because a portion of the EMF exposure within schools is due in some instances to nearby transmission and/or distribution facilities. To the extent that fields from these facilities would have to be reduced to achieve the standards, it may be necessary for the CPUC to enact a decision dealing with such situations, although it should be noted that dealing with internal sources alone would address at least 90% of the classrooms with elevated fields. Similarly, the CDE can adopt Technology Standards that address internal sources. However, any Technology Standards that affect transmission and/or distribution facilities would have to be adopted by the CPUC. The CDE could enact a regulation requiring schools to Enforcing the Electrical Code, but, as with the Field, Personal, and Technology Standards, would have little ability to enforce compliance unless provided additional authority and resources by the Legislature. Were a stumbling block to appear in the enactment of any of these options, it is always possible for the relevant agency to ask the Legislature to create new law to resolve it.

Table 5.4. Summary of agency roles in implementing exposure and risk reduction options. CPUC-California Public Utility Commission, CDE = California Department of Education, LD= Local districts, CDHS = California Department of Health Services.

Option	**CPUC**	**CDE**	**LD**	**CDHS**	**Legislature**
1. Eliminate programs	rescind 93-11-013	rescind siting guidelines	implement	make finding of no risk recommend programs be eliminated	rescind siting guidelines
2. Status quo	oversee 93-11-013	enforce siting guidelines	implement	monitor research provide tech support	
3. Prohibit increases	choose level & enforce		implement		
4. Field standard	choose level & enforce authorize rate-payer share of cost	identify level	implement	make recommendation	enact CDE standard provide state $
5. Personal standard		identify level	implement	make recommendations	enact CDE standard provide state $
6. Technol. standard	set and enforce standards	set standards	implement	make recommendations	enact CDE standard provide state $
7. Enforce electrical code		make policy	implement	make recommendation	enact CDE policy provide state $
8. Address all risks		establish program	implement	make recommendations	enact CDE policy provide state $

With regard to potential liability, decisions in recent court cases in California have greatly reduced the potential for litigation on a range of EMF issues. Therefore, assuming that options are implemented in accord with established legal and regulatory procedures, there is little if any liability risk associated with any of the options.

5.2.5 Administrative effort

We define administrative effort as those activities that are necessary for implementing a policy option but do not involve structured data gathering, engineering design, or actual mitigation. Thus, administration would include planning, rule making, protocol and standards development, compliance oversight and enforcement, and reporting. It would not include, for example, the costs of EMF surveys to identify and diagnose out-of-compliance situations, EMF post-mitigation surveys to assure that the mitigation is effective, or the costs of mitigation itself. Nor, for those options that do not involve mitigation, would it include the costs of terminating existing programs (*Eliminate Existing EMF Programs*) or monitoring ongoing research (*Status Quo*). In general, administrative costs would be incurred by state agencies responsible for developing legislation and regulation and overseeing implementation and enforcement, as well as by individual school districts and schools responsible for implementing a policy. At the least, schools districts would have to provide information to one or more state agencies. Though there are no systematic studies of the size of administrative costs relative to other program costs, the cost estimates summarized in Section 5.2.3 strongly suggest that administrative costs are likely to be small compared to the costs of surveying, diagnosis, and mitigation. Despite this, other research suggests that the administrative structures of regulatory programs, independent of their cost, can have a large influence on the acceptance of a program and the degree to which it is readily complied with. Thus, complicated and/or rigid systems of rules, procedures, funding requirements, and/or reporting obligations can undermine support for programs, reduce compliance and effectiveness, and affect perceptions of their fairness. In most cases, such administrative aspects of policies have more to do with the specifics of implementation than with any inherent features of the policies themselves.

Given the necessarily general descriptions of the policies, and the fact that administrative effort will depend to a large extent on the specific implementation pathway(s) (Section 5.5), we constructed a subjective framework (Table 5.5) for estimating the relative (as opposed to the absolute) levels of administrative effort for each policy option. We identified four key components of administrative effort (planning, standard setting, rule making, and compliance) and assessed which options would occupy the most extreme (i.e., high and low) positions for each component. In Table 5.5, “0” refers to little or no effort and “1,” “2,” and “3” refer, respectively, to small, medium, and large amount of effort, all considered with reference to the *Status Quo* as a baseline. For example, the *Status Quo* and *Enforce Relevant Provisions of National Electrical Code* received a “0” for rule making because they depend on existing rules and procedures. Similarly, *Field and Wirecode Standards* received a “3” for compliance because it requires managing an ongoing compliance monitoring program that would measure fields repeatedly over time. In contrast, *Technology-based Standards* require monitoring to ensure that technological fixes are implemented but monitoring requirements then fall off steeply. Such a ranking is clearly a subjective exercise. It represents the authors’ best effort and other analysts might have somewhat different views about the level of cost associated with each option.

Table 5.5. Relative differences among policy options in terms of the key components of administrative effort. Policies are compared on a qualitative scale, with 0 lowest and 3 highest.

	Component of Administrative Cost			
Options	**Planning**	**Standard Setting**	**Rule Making**	**Compliance**
1. Eliminate programs	1	0	0	0
2. Status quo	0	0	0	0
3. Prohibit increases	2	1	1	1
4. Field standards	2	2	2	3
5. Personal standard	3	3	2	3
6. Technology standards	2	2	2	2
7. Enforce electrical code	1	0	0	2
8. Address all risks	3	3	3	3

5.2.6 Adaptability to future changes in knowledge

There is little doubt that understanding of EMFs and their potential health effects will continue to expand and improve. In such circumstances, one risk in implementing policy is that future knowledge will reveal it to be misguided or ineffective. However, the risk of implementing ineffective policies can be minimized or hedged against to some extent by ensuring that policies that are implemented are adaptable to changes in knowledge. There are two kinds of possible future changes in knowledge. One deals with how certain we are that EMF exposure is hazardous at all. The other concerns what aspect of exposure (e.g., time-weighted average, high-frequency content) can predict risk. Adaptability can be evaluated in terms of either or both kinds of changes in knowledge.

One important distinction between policy options depends on whether mitigation is required now or not. The *Eliminate Existing EMF Programs* and the *Status Quo* options require no great expenditures now and preserve the option to take action in the future should the hazard evidence become clearer. The options that require significant mitigation investment now would create stranded costs if EMF turns out to be harmless. On the other hand, if EMF exposure should turn out to be hazardous, the unavoided health effects incurred under the no-mitigation policies would be stranded costs. Which of these stranded costs is larger depends on assumptions about EMF mitigation costs and health impacts as well as judgments about the prior probability that EMF exposure is hazardous. Here we present a simple decision model of this "wait and see" decision to illustrate how the most important factors in the decision are related.

Consider a decision to reduce EMF exposure in all existing schools either now, in year Y_o, or in some future year, Y_c, in which scientific consensus is reached that EMF exposure is either harmful or harmless. Let p be the odds (as assessed today) that EMF exposure is harmful. Let R be the annual population risk (morbidity and mortality) from not mitigating EMF risk, in the event that EMF is harmful. And let W be our willingness to pay to avoid a unit of annual population risk. For simplicity, we will ignore discounting effects because these are small compared to uncertainties in some other variables (e.g. willingness to pay and health effects). A decision tree representing this decision is shown in Figure 5.1.

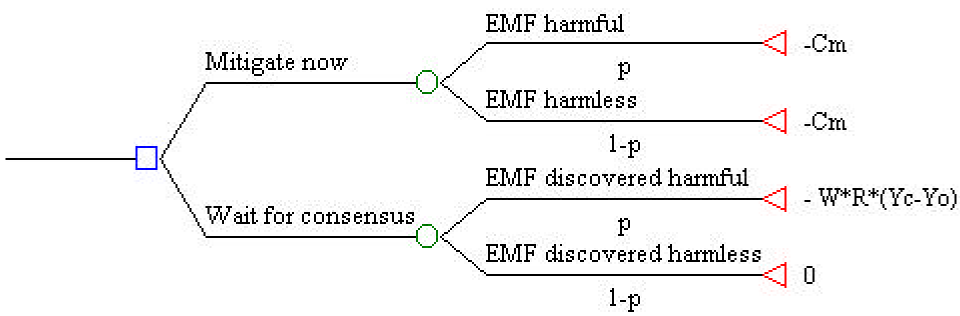

Figure 5.1. Decision tree illustrating the wait and see decision. Mitigation and health costs of each outcome are listed on the right. Circles are chance nodes with probability p that EMF is harmful. Other variables are as defined in the text above.

Note that, for simplicity, we only consider existing schools. Note too that the useful lifetime of the existing school stock does not appear in this model because the health cost streams for the "now" and "wait" options are the same for years beyond the consensus year.

By the decision model in Figure 5.1, one should mitigate now if mitigation costs are less than

$$C_m < p * W * R * (Y_c - Y_o)$$

This makes qualitative sense. We should mitigate now if the probability of harm (*p*) is high, if our willingness to pay for a unit of risk reduction (*W*) is high, if EMF morbidity and mortality (*R*) is high, and if we expect many years to elapse (*Yc-Yo)* before consensus is reached.

Uncertainty about the risk-predictive power of specific aspects of exposure creates more complicated considerations. It is helpful to think of two cases, one in which risk is proportional to time-weighted average 60 Hz exposure, and one in which risk is proportional to some measure of exposure to high-frequency magnetic fields (transients). How robust a given mitigation policy is in the face of a shift in knowledge from one exposure metric to the other depends on how much exposure of one type or another is produced by a given source. Transmission lines produce very low transient fields, but can produce large 60 Hz fields. Therefore, a policy to reduce exposures to 60 Hz fields, either by reducing transmission line fields or keeping people out of those fields, would have high "regret potential" should transients prove to be the biologically effective agent. By contrast, both distribution lines and internal sources each produce both 60 Hz and transient fields, so a policy to reduce spatially-averaged 60 Hz fields by reconfiguring distribution lines or fixing net current sources would substantially reduce transient fields as well. A policy to reduce transient fields by placing power conditioning filters on service drops and internal circuits, however, does little to reduce 60 Hz fields.

The cost-benefit model of field-strength standards described in Section 6 deals with this dose metric problem by reducing the efficacy of mitigation based on time-weighted average 60 Hz exposure by some factor that depends on one's judgment about the likely correlation between the time-weighted average exposure and the "true" dose measure. In the current version of the model, mitigation efficacy is assumed to be the same for all sources. Should more information become available on the relative efficacy of reducing 60 Hz versus transient fields, however, the efficacy of field reduction can be adjusted differently for each source, depending on its exposure spectrum.

The adaptability of each option can also be evaluated in terms of how readily it can be reversed or rolled back if new evidence shows it to be unwarranted, as well as the costs of such reversal. Reversibility is unlikely to be an issue for the *Eliminate Existing EMF Programs* option because the evidence leading to choice of this option would, we presume, be strong enough and certain enough to remove the likelihood that the issue of EMF hazards would arise again. Reversibility is an issue for the *Status Quo* option only under risk scenario #4 in which EMFs are found not to be a hazard. The steps involved in reversing the *Status Quo* are covered in the description of the *Eliminate Existing EMF Programs* option (Section 5.1.1). If, on the other hand, EMF exposure were found to constitute a hazard, as in risk scenarios #1 or #2, the impact on programs of the *Status Quo* would be to expand them, but this does not constitute a policy reversal.

Reversibility is primarily relevant to the options that involve standard setting and exposure reduction or limitation. Among these, *Technology-based Standards* (Section 5.1.6) are least reversible. Once in place, technological solutions are difficult and costly to undo. Field standards, whether applied to areas (Section 5.1.4) or individuals (Section 5.1.5), are more easily reversed. For example, changes in space usage can be reversed readily. In comparing engineering and space usage approaches to meeting field standards, usage approaches gain an advantage from the fact that costs are spread out over time (inconvenience costs are incurred on a continuing basis), whereas engineering solutions present all costs up front. Of course, continuing costs can be truncated if it is later discovered that EMF exposure is innocuous. Similarly, a prohibition on increases in current loading and/or exposure from transmission lines near schools (Section 5.1.3) could easily be terminated if needed. In that situation, there may be stranded costs if the limitation near schools had required increased capacity elsewhere. On the other hand, stranded costs might be reduced or eliminated if, at the time when EMFs are found innocuous, growth in electricity demand has created a situation in which both the newly created and (temporarily) abandoned capacities are needed.

Reversibility is not relevant for the *Enforce Relevant Provisions of National Electrical Code* option, since it is hard to envision a situation in which statewide policy makers would explicitly say these provisions of code should not be enforced. Nor is reversibility very relevant for the option to address all risks in school statewide. This is because the statewide evaluation of risks would be much less susceptible to changes in knowledge about EMF, since it would be addressing a much wider range of risks.

In addition to the effects of changes in knowledge about the biological effects of EMF, one also should consider the effects of possible technology change in choosing among EMF management options. New engineering methods for reducing magnetic fields from power systems have emerged over the past decade, and additional advances are possible, particularly for internal sources where field reduction research has been very limited. There are different schools of thought regarding the effect that technology change considerations should have on the selection of an EMF management option. On the one hand, maintaining the status quo buys time to wait for new mitigation options to be invented. On the other hand, any of the field reduction options (Options 3 through 7) create demand for magnetic field reduction technologies, which would theoretically stimulate innovation among suppliers of those technologies.

5.2.7 Summary of exposure reduction options

The above attribute-by-attribute discussion of exposure reduction options is presented in tabular form in Table 5.6. Here, we provide a brief option-by-option analysis.

<u>Eliminating existing EMF programs</u> would clearly make sense if scientific consensus were reached that EMF exposures are harmless. Such consensus is unlikely to happen however, given the current weight of epidemiologic evidence suggestive of a health effect, and the tendency of epidemiologic investigations to

generate occasional controversial results. In the absence of substantial scientific consensus that EMF exposure is innocuous, eliminating existing EMF programs may be politically impossible and ethically undesirable. Eliminating existing programs would save the costs of those programs (insofar as they affect schools). These costs are difficult to estimate because there are no data on the costs of compliance with either the School Siting Guidelines or CPUC 93-11-013. Eliminating existing programs would have only a small impact on population exposure to EMF in schools. This is because existing programs affect only a very small number of schools. Nonetheless, eliminating existing programs would convey some additional risk under the possible and definite risk scenarios. Eliminating existing EMF programs would require action by a number of state agencies as well as the State Legislature. These actions could be precipitated by a finding by CDHS that EMF exposure poses no significant risk.

<u>Maintaining the status quo</u>, by definition, incurs no additional costs and accrues no additional benefits compared to existing activities. This policy leaves decisions on EMF avoidance up to local officials, thus wealthier districts are more likely to take action. This policy leaves open the possibility of future action should evidence on EMF hazard become more compelling. In addition, since this policy involves relatively modest investment in exposure control, it largely avoids the risk of sunk mitigation costs, should EMFs be exonerated in the future, or should current mitigation measures prove ineffective. By definition, this policy requires no changes in law or in administrative procedures.

<u>Prohibiting increases in EMF exposure from power lines near schools</u> would require sending power along alternative routes that do not pass by schools. This may require construction of additional power line capacity. Moreover, the power added to alternative routes will itself result in magnetic field exposure to the general population, including school children. This exposure may exceed that avoided by restricting magnetic fields of power lines at schools. Although there may be specific schools and neighborhoods for which the particular power system and housing configurations would make this option a cost-effective alternative, a statewide prohibition on increases in EMF from power lines near schools is inferior to other statewide options that would address EMF exposures from power lines (e.g., a technology standard requiring low-field configurations for those segments of power lines that pass schools). Finally, as power lines are responsible for only a small fraction of magnetic field exposure at schools, this policy alone would have little effect on statewide population risk from schooltime EMF exposures.

<u>Implementing magnetic field strength standards</u> would greatly reduce exposures to the most highly exposed individuals at schools. Because the bulk of the population exposure from EMFs at schools is from fields less than 2 milligauss, however, magnetic field standards would have to be quite stringent to make substantial reductions in total EMF exposure at schools. Field strength standards would apply equally to everyone, so no individual would have residual EMF risks that greatly exceed the average risk. The

statewide cost of a field-strength standard depends greatly on the field level chosen for the standard, ranging from roughly $15 million for a 5 mG standard (classroom average) to $120 million for a 1 mG standard.

Implementing personal exposure standards has attributes similar to implementing field strength standards. For a given exposure level, however, personal exposure standards would have lower direct mitigation costs than field strength standards, because the personal exposure standard permits moving of people to achieve compliance. Personal exposure standards would be more complicated to administer than field strength standards, however, because one would need to make measurements of occupancy density and duration in various school areas. The implementation costs of this option would grow in proportion to the level of detail at which time-use factors are considered.

Implementing technology-based standards has the virtue of simplicity, because it requires no area-by-area EMF measurements. Although the policy treats all schools equally, older schools may be more affected than newer ones, simply because older schools are more likely to have net currents, the most likely target of a technology-based standard. Because technology-based standards do not take account of actual field levels or proximity of people to sources, they achieve lower field reductions for a given expenditure on mitigation than either field strength or personal exposure standards applied to the same sources. This disadvantage may be offset by the low administrative costs of technology-based standards.

Enforcing some provisions of the National Electrical Code addressing net currents in school wiring would convey a double benefit by reducing both EMF levels and the risk of electrocution and fire associated with improperly configured internal wiring. There are several variants of this option. The most expensive (about $75 million) would involve electrician visits to all schools to find and eliminate all wiring errors, regardless of the field levels they produce. Less expensive options would involve correcting only those errors that create fields above some threshold (e.g., it would cost about $16 million to fix errors creating average classroom fields exceeding 2 mG), or correcting only those errors encountered during routine maintenance of electrical systems. Because this option only addresses EMF from net currents, however, it would leave untreated situations involving exposures to strong fields from other sources, including power lines.

Addressing EMF as part of a program to address all health and safety risks in schools would undertake reduction of both EMF and non-EMF risks in schools in order of their cost effectiveness for risk reduction. Such a policy would result in the greatest total risk reduction for a given expenditure. Although little is known about the cost-effectiveness of measures to reduce non-EMF risks in schools, some measures, such as scheduled hand washing to reduce risk of intestinal illness, are clearly quite inexpensive. Without further study of the costs of reducing non-EMF risks in schools, it is impossible to say how much priority would be given to EMF exposure reduction under this policy. By prioritizing by cost-effectiveness, this policy may not address situations involving high EMF or non-EMF risks that are very expensive to fix. If EMF exposure reduction did not receive priority under this policy, the policy might appear unattractive to adherents of the social justice or libertarian world views.

Table 5.6. A comparison of eight policy options for addressing EMF exposure in schools.

Policy Option	**A. Potential for exposure reduction compared to status quo**	**B. Costs compared to status quo**	**C. Ethical implications (distributive fairness)**	**D. Legal and organizational compatibility**	**E. Administrative effort *0 = least* *3 = most***				**F. Adaptability to future changes in knowledge**
					Planning	Standard setting	Rule Making	Compliance	
1.Eliminate existing EMF programs	Small increase in exposure over status quo.	-Elimination of small but uncertain existing costs of compliance. -Perception that the decision is unfair could raise administrative costs.		<u>CPUC</u>-Rescind 93-11-013 <u>CDE</u>-Rescind siting guidelines <u>CDHS</u>-Make finding of no risk & recommend programs be eliminated <u>LEGISLATURE</u> -Rescind siting guidelines	1	0	0	0	Preserves the option to take action in the future
2. Maintain the status quo, continuing existing EMF programs	Reduction efforts made at discretion of local decision makers	-Most costs borne by individual school districts -Case-specific costs can be quite high	-Would freeze existing situation, with any existing inequalities	CPUC-oversee 93-11-013 <u>CDE</u>-enforce siting guidelines <u>CDHS</u>-monitor research	0	0	0	0	-Preserves the option to take action in the future -Wait-and-see approach
3. Prohibit Increases in EMF exposures from power lines near existing schools	-Little impact on school exposure. -May increase exposure along alternative routes	-Survey and monitoring expenses -Possibly millions for new or upgraded lines to reroute power.	Would freeze existing situation, with any existing inequalities	CPUC-identify level and enforce	2	1	1	1	-Since loads grow steadily over time, it is easy to make use of stranded capacity again.
4. Implement magnetic field strength standards	-Depends on the level at which standards are set -Substantial exposure reductions for individuals who are most exposed	-Statewide costs increase from roughly $15 million for a 5 mG standard to $120 million for a 1 mG standard.	Treats all schools and all individuals equally	CPUC-identify level or configuration and enforce <u>CDE</u>-identify level <u>CDHS</u>-make recommendations <u>LEGISLATURE</u>-enact CDE standard	2	2	2	3	- Involves substantial sunk costs which would not be recoverable.

5. Implement personal exposure standards	-Depends on the level at which standards are set -Substantial exposure reductions for individuals who are most exposed	-Compared to field strength standards, direct mitigation costs are less but implementation is substantially more complicated.	Treats all schools and individuals equally	CDE-identify level CDHS-make recommendations LEGISLATURE-enact CDE standard	3	3	2	3	- Involves substantial sunk costs which would not be recoverable.
6. Implement technology-based standards	-For the same investment, will yield lower exposure reductions than either field strength or personal exposure standards -No surveys or source id are necessary	-Depends on which sources are targeted -No expense for surveys and source id -Lower administrative costs than for field strength or personal exposure standards -Less economically efficient than other methods	Impose equal requirements on all parties, though older or lower SES schools may shoulder higher costs (e.g., because they have more net currents and nearby power lines).	CPUC-set and enforce standards CDE-set standards CDHS-make recommendations LEGISLATURE-enact CDE standard	2	2	2	2	-One of the least adaptable options -Not easily reversible
7. Enforce some provisions of the National Electrical Code addressing net currents in school wiring	-Would eliminate roughly 2/3 of school-time population exposure -Reduces fire and shock hazards, and over-voltage damage to electrical equipment	-Statewide cost to find and repair all net current sources is roughly $75 million. Cost to repair only those creating > 2 mG in classrooms is much less (~$16 M). -Costs could be reduced by testing and repairing net currents only as other electrical work is done.	Treats all schools equally, though older or lower SES schools may shoulder higher costs because they have more net currents per school	CDE-make policy CDHS-make recommendations LEGISLATURE-enact CDE policy	1	0	0	2	Reversibility is not an issue, since provisions of the National Electrical Code should be enforced regardless of EMF concerns
8. Address EMF as part of a program to address all health and safety risks in schools	-Depends on extent to which EMF risk reduction is more cost-effective than reducing non-EMF risks.	-Little data on the feasibility or costs of reducing non-EMF risks in schools, although some (e.g., scheduled hand washing) are quite inexpensive.	Could be designed to reduce risks in schools with highest background risks, or with most cost-effective opportunities for risk reduction. Attractive under utilitarian framework. Places no weight on "polluter pays" principle.	CDE-establish program CDHS-make recommendations LEGISLATURE-enact CDE program	3	3	3	3	Reversibility not an issue since the statewide evaluation of risks would be addressing a much wider range of risks

5.3 Description of communication and procedural options

The statewide research and education program established by CPUC decision 93-11-013 provides for a coordinated set of activities designed to support decision making at both the local and statewide levels. However, this program is scheduled to end in the near future, and there is no specific provision for statewide activities beyond this date. In addition, the procedural aspects of environmental policies that relate to EMF are tailored to the current condition of scientific uncertainty. It would be helpful to consider how these might be modified under the other risk scenarios presented above (Section 4.1). Finally, there are inconsistencies between agencies' EMF-related procedures and/or guidelines that create disparities from place to place in the way that the same situation is dealt with.

In Sections 5.3.1 through 5.3.5, we present five policy options that could help structure decision making in these areas. They all assume the existence of risk or potential risk from EMF exposure and address many of the issues described in Tables 3.1 and 3.2 related to minimizing costs for school districts, equitably distributing costs and risks, and ensuring fairness. These options are primarily procedural, with little if any emphasis on actual mitigation through engineering solutions. Table 5.7 shows the distribution of the alternative policies across the hazard scenarios and decision settings defined in Section 4.

5.3.1 Option 9: Develop and implement information program

This option involves developing information to help school officials respond to concerned parents and teachers by completing a process of defining and evaluating EMF problems, determining field management options, and acting based upon their school's circumstances and school community's feelings about risk avoidance. To be effective, any such information program should emphasize the usability of information and make acquisition of information more convenient. One approach would be to include a proactive element similar to utility "bill stuffers" on EMF and other issues. In addition, the program should also incorporate measures for evaluating its effectiveness over time in terms that are relevant to its target audiences. Based on our interviews with local school officials, a primary need for decision makers at this level is to resolve EMF-related concerns with a minimum of conflict by reference to authoritative background information and clear advice about specific policy options.

Table 5.7. Distribution of the five communication and procedural options across the risk scenarios and decision settings defined in Section 4. Section numbers in parentheses refer to the report sections where each option is described.

Decision Settings	Risk Scenarios			
	Hazard and Dose Response Understood	**Hazard and Dose Response Not Understood**	**Hazard Uncertainty Persists**	**No Hazard**
New School	Information program (5.3.1) Research values (5.3.2)	Information program Research values	Information program Research values	Information program
Build or Upgrade Line at Existing School	Information program Research values Siting consistency (5.3.3) CEQA review (5.3.4) Utility services (5.3.5)	Information program Research values Siting consistency CEQA review Utility services	Information program Research values Siting consistency Utility services	Information program
Existing School and Power Facilities	Information program Research values Utility services	Information program Research values Utility services	Information program Research values Utility services	Information program
Local and Internal Sources at School Site or in Buildings	Information program Research values	Information program Research values	Information program Research values	Information program

Such an information program would be useful because of the present lack of any coordinated and comprehensive source of information targeted directly at schools. (See Section 5.1.2 for a description of the status quo.) Currently, school officials may refer to relevant CPUC decisions, consult with their local utility, with local and/or state health authorities, the U.S. Environmental Protection Agency, federal research program (RAPID) staff, local experts and organizations such as the Electromagnetic Radiation Alliance. They may be generally aware of EMF issues from media reports. Concerned parents may also have professional or other relevant expertise that they may use to help or influence school officials in dealing with EMF. For example, we have encountered situations where parents who were trained in epidemiology, electrical engineering, or risk assessment were active participants in the decision process at the local level. In theory there may be some benefit to having an array of information sources available. However, in fact, individual schools and school districts face a patchwork of information sources, many of them not specific to schools, and potentially high costs in obtaining and applying this information.

The program's design and development would be guided by further, in-depth interviews with school representatives and evaluation of existing information sources. This needs assessment would identify and evaluate existing sources of information and determine gaps, issues of trust, accessibility of information, and how school officials view existing information resources in light of their own circumstances. The assessment would provide a basis for distinguishing between problems that need to be addressed with either better information, better access to information, or assistance in applying information. Specific program elements might include publications, a web page on schools/EMF, and referral/advisory services. Because school districts, and their needs, differ, any statewide information program should enable districts to choose from a menu of items to construct the most appropriate set of information. Reflecting an important theme in our interviews with local school officials, a major goal of this policy should be to protect school districts from the pressure to become public health experts by providing authoritative background information and clear policy advice.

An information program might include both publications and advisory or referral services. Publications could include an EMF Management Handbook which would borrow from previous publications in the public domain yet target problems in schools and school administrators as an audience. Suitable topics include:

- EMF health concerns pertaining to children
- existing information sources and where to obtain them
- tips on how to work with concerned parents and staff
- explanation of EMF surveys, spot measurements and exposure assessment
- summarization of California Schools Exposure Assessment
- what to expect from measurements and how to obtain them
- field management strategies
- information on approximate costs for mitigation options
- case studies of how other schools have handled their EMF problems

Other publications could be used to provide status reports and exchange information on current events, including issue management in schools where concerns have surfaced, and the California research program. This information could be presented in a periodic newsletter, and more frequent updates could be posted on one or more web sites (there are an estimated 70) devoted to schools. The newsletter could deal exclusively with EMF, or it could deal with EMF in a broader context of health and safety issues that are important to school administrators and parents; such as drug prevention, transportation safety, and environmental hazards.

A referral or advisory service could include means of making the implementing agency available to field questions on EMF. It could also maintain a list of local, state and federal agency contacts, local utility contacts, EMF consultants, and sources to consult for further information. Efforts would be made to save school representatives time in getting directly to knowledgeable sources. Referral and advisory services could also include assistance in developing requests for information from the local utility and evaluating the suitability of any response.

5.3.2 Option 10: Measure values of the public

There has been a significant effort to date to determine whether EMF exposure can affect health, to identify sources of exposure, and to engineer field management alternatives. Relatively little research has been devoted to learning opinions of the lay public with regard to the various value choices inherent in choosing a policy for managing EMF in schools. By systematically eliciting such opinions, decision makers can have better assurance that their choices are aligned with the sensibilities of the general public. Key value issues for which public opinion might be elicited include:

- How much concern are EMF risks compared to other risks in schools?

- Is it more important to reduce magnetic fields from power lines than fields from internal sources, even when it is more expensive to address the former?

- How much should fairness be traded for economic efficiency (e.g., how much weight should be placed on reducing individual risks versus population-average risk)?

- Who should pay to address EMF exposures from different sources in schools?

What is the best framework for selecting policy implementation levels? Options include(a) Acceptable risk - a level of control chosen so that risks after mitigation are acceptably small, (b) Lowest observable risk - a level of control chosen to assure that no student is exposed above levels associated with increased risk in epidemiological studies (e.g., about 2 mG), (c) EMF exposure norms - choice of a level so that school exposures are not larger that those encountered at home, and (d)Cost-benefit - choice of a level of control so that the average marginal cost of control equals the average marginal willingness-to-pay for policy benefits (e.g. risk reduction, public confidence, etc.)

With careful experimental design and modern elicitation methods, it is possible to obtain reproducible and meaningful answers to such questions from representative samples of lay people.

This option could be implemented by the CDHS under its broad policy-making responsibility regarding potential health risks.

Which agency would oversee research to elicit lay peoples' values on these questions is not clear, since many of the issues cut across responsibilities of several agencies.

5.3.3 Option 11: Standardize siting guidelines for schools and electrical facilities

In California, the CDE has adopted statewide guidelines to limit the location of new school campuses to sites that are prescribed distances from electric transmission lines (Section 4.2). The purpose of these guidelines is to effectively eliminate transmission lines as a source of EMF exposure on school grounds. However, similar provisions have not been adopted relative to siting of utility facilities. Thus, after a school is constructed, there is nothing in the siting policies of either the CPUC or municipal utilities to prevent transmission lines and substations from being constructed within the “buffer zone” originally created by the school siting guidelines. This can undermine the effectiveness of the CDE’s efforts to limit EMF exposures from transmission facilities. A policy to establish conformity among the various siting authorities would be applicable under risk scenarios #1, hazard identified and dose-response understood, #2, hazard identified and dose-response not understood, and #3, present uncertainty persists.

Achieving conformity in siting and permitting guidelines would require cooperation among the CPUC, the CDE, the local agencies that regulate municipal utilities, and the electric utilities themselves. The primary intention would be to achieve greater consistency in siting decisions statewide. Implementation would involve CPUC decision making and parallel actions for municipal utilities. It would also be enhanced by the modification of each utility’s EMF design guidelines. This policy would provide an opportunity for updating the school siting guidelines with new information, particularly under risk scenarios #1 and #2. For risk scenario #3, present uncertainty persists, the present siting guidelines could simply be adopted by the CPUC and municipalities. Alternatively, the guidelines could be adapted to address magnetic, rather than electric, fields, since magnetic fields are the source of health concerns. Adopting this policy is well within the existing authorities of the agencies involved.

5.3.4 Option 12: Include EMF in CPUC CEQA review

This policy option would modify the CPUC’s current CEQA review process to include a more detailed evaluation of the potential EMF-related health risks from proposed transmission facilities. It would be applicable under risk scenarios #1, hazard identified and dose-response understood, and #2, hazard identified and dose-response not understood. It presumes that additional scientific information has shown EMF to be a health hazard. Its intent is to ensure that the environmental review process reflects this knowledge.

The proponent of any electric power line project subject to the California Environmental Quality Act (CEQA) and for which CPUC approval is required (i.e., investor-owned utility projects greater than 50kV) must submit an environmental impact report (EIR) to the Commission. As the lead agency for such projects, the Commission has adopted rules for fulfilling its responsibilities under CEQA (see Rule 17.1 Special Procedure for Implementation of the California Environmental Quality Act of 1970 - Preparation and

Submission of Environmental Impact Reports). The purpose of an EIR is to identify project alternatives, compare the impacts of each, and identify measures that could be incorporated to mitigate significant adverse impacts. While there are no strict criteria for determining the significance of an impact, the Commission's rule notes that where there is, or where there can be anticipated to be, a substantial body of opinion that considers an impact to be significant, it shall be considered significant and discussed in detail in the EIR. There is no distinction made between expert and other opinion at this level.

At present, EMFs are discussed in project EIRs in a descriptive manner only. EIRs summarize the fields expected to be generated by the proposed project and the effect of low-cost and no-cost measures included in the design to reduce such fields. Similar information is required by the Commission as part of the permit application process (see General Order No.131-D, Section X.A. Application for CPCN or Permit to Construct). However, there is no requirement for evaluating this information in light of studies of the potential health risks of EMFs. This present policy is based on a past decision of the Commission, referred to as the Kramer-Victor decision, which noted that the project EIR found the potential risk of health effects from exposure to EMF to be too speculative to be categorized as "significant."

The Commission has previously (Decision 93-11-013) identified CDHS as the appropriate agency for performing and tracking EMF research, informing the Commission about the results of such research, and making recommendations about the significance of any health impacts. Thus, this policy would most likely be implemented following a formal recommendation from CDHS that scientific evidence now confirms that EMFs pose a health hazard (i.e., risk scenario # 1 or # 2). At such time, expanding the CEQA review process to include EMFs as a health risk would provide a means to improve communication about potential EMF health effects, increase dialog about engineering and other measures to reduce exposure, and air differences in judgments about the potential significance of effects. At that point, EMFs would be treated in the same manner as other health and environmental concerns that had risen above the threshold of significance, providing a formal framework, with legal standing for participants, for addressing important environmental issues.

If siting guidelines for schools and transmission facilities are standardized (Section 5.3.3), it may make it unnecessary to expand the CEQA review process. Thus, if future transmission facilities are sited far enough from schools to keep EMFs below minimum levels, and if such siting guidelines are accepted as an adequate response to available scientific knowledge, then case by case CEQA review may not be useful. However, it may be desirable to revise the siting guidelines to address magnetic, rather than electric, fields.

The CPUC has a broad mandate to evaluate the safety, health, and environmental impacts of utility projects. Article XII, Section 6 of the state constitution authorizes the CPUC to establish rules for utilities under its jurisdiction. Further, Public Utilities Code Section 451 requires regulated public utilities to operate in a manner that promotes the health and safety of its patrons, employees, and the public. To implement these responsibilities, the CPUC issued General Order 95, which sets safety standards for the construction of electric power lines. In addition, Public Utilities Code Section 1002 requires the Commission, in granting any certificate, to consider the potential effects of the project on community values and on the environment. The environmental impact review process under CEQA provides a structured method for implementing these broad mandates, especially for complex issues such as EMF. Expanding the CEQA review process is thus well within the regulatory mandate of the CPUC. This policy could be implemented through the mechanism of a formal CPUC decision following findings and recommendations from CDHS that EMFs posed a health risk.

5.3.5 Option 13: Increase the availability of utility technical services to schools

This policy would require a significant expansion of utilities' existing measurement programs to provide more comprehensive assistance to schools in surveying EMF and identifying, comparing, and choosing among measures to reduce EMF. As described below, the range of technical services included in this policy could be adjusted depending on the available scientific knowledge about EMF's potential health effects. This policy could therefore be scaled to apply to risk scenarios #1, hazard identified and dose-response understood, #2, hazard identified and dose-response not understood, and #3, present uncertainty persists.

At present, investor owned utilities, but not all municipal utilities, provide magnetic field spot measurements and general information on EMF for customers at no charge. CPUC Decision 93-11-013 required investor owned utilities to provide EMF measurements free of charge at customer residences or workplaces, and to include written measurement results and educational materials on EMF sources. However, at the time of the decision, the practice among investor owned utilities of providing measurements to customers was so widespread that the CPUC considered this a moot point. In addition to the spot measurements available from utilities, information on potential health effects is available from the California State Department of Health. While this information can be useful in determining if elevated levels of EMF are present at a school, it does little to assist school officials and parents in subsequent decision making about whether and how to respond to any elevated levels that are found. Little technical assistance is available to schools unless they have the resources to hire a consultant. There is thus a gap between general information about EMF levels and possible health effects on the one hand and the kind of information needed to assess alternatives for reducing EMF levels and/or exposures on the other. This may require specialized instrumentation, technical expertise, and considerable information from the electric utility if utility facilities are significant sources of EMF in the school.

Assistance can be provided by helping customers understand more about their particular circumstances, the possible actions that may be taken, and their relative costs. There is a wealth of information related to field management that may not be readily available to school officials and parents and which, once obtained, may be difficult to interpret and apply to the specific situation. While consultants may ultimately be needed to provide detailed surveys or cost estimates of field management strategies, there is an opportunity prior to this point to conduct somewhat more extensive measurement programs, identify likely sources of elevated fields, and describe and discuss possible responses to EMF concerns. The goal of such an expanded package of services would be to provide the customer with enough information to be generally aware of possible alternatives, understand their cost effectiveness and technical feasibility, structure their decision process, and determine whether to hire a consultant and for what purpose. Under this option, the role of the utility would be to assist in framing the problem and providing practical advice. It would not replace the role of consulting engineering services, as may be needed to develop specific solutions and detailed cost estimates.

The precise package of services provided to schools could be made dependent on the risk scenario, with more services required under scenarios #1 and #2 (hazard identified) than under scenario #3 (uncertainty persists). Other criteria could ensure that schools' needs are met at a fair and reasonable cost to utilities. For example, different levels of implementation could be tied to different EMF levels and/or to whether these derived from internal or external sources. CPUC decision 93-11-013 recognizes that, at present, utilities' measurement programs go beyond the point of interconnection to cover potential sources that are unrelated to transmission and distribution lines. Given that the majority of EMF sources identified in schools are internal, this policy will be most useful if it includes such sources. But utility companies currently have limited expertise in measuring sources on the customer side of the meter, and they have virtually no experience in diagnosing and prescribing mitigation for non-utility sources (e.g., net currents in buildings). Rather than require utilities to acquire such expertise, it may be better to open the service to the private contractors.

This option is well within the existing authority of the CPUC.

5.4 Analysis of communication and procedural options

The options described above differ substantially across a range of factors important to decision makers, including:

- administrative effort
- costs
- implications for equity, fairness, and environmental justice
- implications for liability and potential litigation
- adaptability to future changes in knowledge.

This section compares the communication and procedural options from the perspective of each of these key factors.

5.4.1 Administrative effort and costs

Effort involved in developing and adopting the communication and procedural polices is almost entirely administrative, as defined in Section 5.2.1, given that they include no engineering mitigation activities. The communication and procedural policies are almost exclusively focused on information dissemination, planning, rule making, and protocol and standards development. By definition they exclude structured data gathering and actual mitigation, focusing only on the development and adoption of the policies themselves. Given that there are no costs for these options that are separate from administrative effort, we discuss costs together with administrative effort in this section. As suggested in Section 5.2.1, the costs of administrative policies are more likely to be borne by state agencies responsible for developing legislation and regulation and overseeing implementation and enforcement.

Administrative effort associated with the policies in this section can be separated into two categories, the effort required to define the policy precisely and then enact it and the effort involved in carrying out the policy once enacted. For the first cost category, defining and enacting the policy, the policies fall into two distinct groups. Increasing the availability of technical services to schools (Section 5.3.5) would most probably require extensive discussion and negotiation among utilities, the CPUC, the CDE, and other interested parties because of the potential high costs involved in implementation. Conversely, developing an information program (Section 5.3.1), conducting research on stakeholder values (Section 5.3.2), and standardizing siting guidelines (Section 5.3.3) are all logical outgrowths of existing policies whose enactment would be relatively straightforward. Expanding the CPUC's CEQA review to include EMF (Section 5.3.4) would be contentious and time consuming under present circumstances. However, this policy would only be adopted if additional scientific information resolved existing uncertainty by showing EMF to be a health hazard (risk scenario #1 or #2). In this case, there would most likely be less administrative effort involved in enacting this policy.

As the preceding paragraph suggests, increasing the availability of utility technical services to schools could be potentially costly, depending on which risk scenario is operative, the level of implementation chosen, and the number of schools that use these services. Currently, the percentage of schools that request EMF surveys is small. However, this number would be likely to rise if EMF were found to be a hazard and there would likely be more demand for the expanded set of technical services. Conversely, if EMF were determined to be a hazard, other policies would most probably also be implemented that could reduce the need for schools to depend exclusively on utilities' technical services. For example, an information program targeted at schools (Section 5.3.1) could provide much of the information needed to support decision making.

Implementation costs for all of the other communication and procedural options are likely to be low, especially when viewed in terms of their marginal contribution to the costs of existing related policies. For example, the CPUC's CEQA review process encompasses many health and environmental issues and adding EMF to this list would not entail any procedural changes. Similarly, the Office of the State Architect reviews school plans for compliance with the State Building Code. Adding design guidelines for internal sources would lengthen the review process somewhat but would not require major procedural changes or new regulatory authority.

5.4.2 Implications for equity, fairness, and environmental justice

We use the same conceptual structure used to examine fairness issues for the exposure and risk reduction options (Section 5.2.4).

In terms of the fairness of policy outcomes, implementing an information program and expanding the availability of utility technical services will primarily address imbalances in school districts' access to information needed for decision making. This meets the need and equality fairness criteria for policy outcomes, with the caveat that there may be differences in the level of implementation between investor-owned and municipal utilities, which are not regulated by any statewide agency. However, to the extent that utilities end up paying for technical services related to internal sources, this would violate the contribution fairness criterion, since utilities do not contribute to these sources. Standardizing siting requirements across agencies also meets the equality fairness criterion by ensuring that all siting decisions involving schools and transmission facilities are held to the same standard. Siting requirements may violate the compensation fairness criterion to the extent that schools differ in their ability to pay for compliance and costs are not reimbursed by the state. They may also violate the aggregate welfare criterion if the costs of compliance divert limited school funds from other priorities with a perceived higher value. There are no particular fairness impacts associated with the outcomes of the remaining options (research stakeholder values and expand the CPUC's CEQA review).

To the extent that these options help address imbalances in existing access to information and services, they may address environmental justice issues. However, by treating all schools equally, they are also neutral in terms of the compensation fairness criterion. They therefore do not provide any targeted attention to minority communities where environmental justice impacts may be present (but see following discussion of the fairness implications of policy implementation).

Several of these policies could be implemented in ways that affect their perceived fairness. For example, the information and technical services programs could be targeted more specifically at poorer schools or at categories of schools with higher exposures. This would address the need and compensation fairness criteria, respectively. Targeting information products at minority schools would help address any environmental justice issues. Providing support to schools so they can participate more actively in the CEQA review of proposed nearby transmission facilities would meet the need fairness criterion. If support were scaled with regard to district socioeconomic status, then this would meet the compensation fairness criterion and, in some cases, address environmental justice concerns.

5.4.3 Implications for liability and potential litigation

All the communication and procedural options fall well within the existing authorities of responsible agencies. Please see Section 5.2.5 for a more expanded discussion.

5.4.4 Adaptability to future changes in knowledge

The fact that these options are essentially informational and procedural in nature makes them, in principle, extremely flexible and adaptable. All of them could readily be modified through existing administrative procedures, with little or no loss of stranded capital costs, with the exception of the provision of expanded technical services.

5.5 Implementation and its effects

Sections 5.1 - 5.4 have described a set of policy options that directly address several different aspects of the EMF in schools problem, such as exposure, access to information, and environmental review. The majority of these options could be implemented in a variety of ways, with equally wide effects on the ultimate financial and fairness impacts of each option. For example, a particular exposure reduction option could be implemented to reduce exposure to below that associated with increased risk in epidemiological studies, to the average of at-home exposures, or to the most "economically-efficient" level, based on cost benefit analysis. To add another level of complexity, the same exposure reduction option could be implemented simultaneously across the state or phased in over a period of time. If phased in over time, this policy could be applied to schools on a random basis, on the basis of EMF exposure levels, according to the relationship of EMF exposure to other risks to children and staff in each school, or by income levels in each school district. Thus, as different ways of arriving at the same outcome, various implementation pathways can be considered as another set of axes in defining where individual policy options lie in the universe of potential responses to this issue (see also Sections 5.2.4 and 5.4.2 for a discussion of the fairness implications of implementation).

In this section, we describe three concepts of justice (libertarian, utilitarian, and social) (Davy, 1996) that lead to fundamentally different implementation pathways for most options, and therefore to quite different impacts on costs, the timing and distribution of exposure reduction, and environmental justice. We then match these against several essential elements of policy implementation to create a framework for enumerating implementation pathways and examining their implications. Finally, we discuss how options could be used in combination. We argue that the nature of the EMF problem in schools necessitates the use of multiple options of different types in order to achieve the goals outlined in Tables 3.1 and 3.2.

5.5.1 Competing notions of justice

As we discussed previously (Section 3), different stakeholders will weight the goals in Tables 3.1 and 3.2 in sometimes radically different ways that reflect corresponding differences in their underlying values. Such values affect stakeholders' preferences not only for final outcomes (e.g., sources targeted for mitigation, degree of exposure reduction) but also for the process through which policy decisions are made. At times, the process of decision making or implementation can be more important to some stakeholders than the decision outcome itself . Many people are more willing to accede to an otherwise unacceptable outcome if they have had an active role in the decision-making process than if they have simply had this outcome imposed on them (Kunreuther and Slovic, 1996; Linnerooth-Bayer and Fitzgerald, 1996). The utilitarian and ethical impacts of alternative policies can often be understood and evaluated only in the context of specific implementation strategies.

While we believe that it is important to extend the policy analysis to consider implementation pathways, we recognize that it would be infeasible to individually consider every combination of policy option and potential implementation strategy; the number of combinations is simply too large. Therefore, we believe it is useful for decision makers to have a framework for organizing and understanding the assumptions and goals that underlie competing proposals for how to implement a given policy. Such a framework can help improve decision makers' ability to meet stakeholders' needs and bridge gaps between divergent positions.

Most of the possible implementation pathways for the options described above arise from one or the other of three basic concepts of justice: libertarian, utilitarian, and social justice. Libertarian justice emphasizes unrestrained interactions between free individuals, and is the basis for market mechanisms such as pollution trading and deregulation. Utilitarian justice assumes that social arrangements should provide for the greatest happiness of the greatest number, and is the basis for cost-benefit analysis and other tools that attempt to maximize the public good by redistributing costs and benefits without regard to property rights or ethical principles. Social justice assumes that social arrangements should favor the disadvantaged, and is the basis for compensatory implementation pathways such as targeting mitigation first at schools in poor or minority school districts. There is an extensive literature that discusses these concepts, and their historical antecedents, at great length (Davy, 1996; Foster, 1998; Kuehn, 2000). However, for our purposes here, they can be condensed as follows:

- Libertarian justice is what is beneficial to rights holders: Maximize liberty.
- Utilitarian justice is what is beneficial to the most: Maximize happiness.
- Social justice is what is beneficial to the disadvantaged: Minimize pain.

These distinct concepts of justice give rise to equally distinct expectations about how policies should be implemented, as discussed further in the following section.

5.5.2 Creating implementation pathways

There is a set of elements that arise in the majority of the policy options described above. These can be expressed as questions that correspond to a subset of the traditional reporter's questions:

- *Who* should the policy focus on?
- *What* source(s) should be addressed?
- *When*$_1$ should the policy be initiated?
- *When*$_2$ should it be implemented at individual schools?
- *Where* in the school should the policy be implemented?
- *How*$_1$ should the policy be implemented technically?
- *How*$_2$ should the policy be funded?

Together with the three concepts of justice, these seven elements form a matrix (Table 5.8) that organizes and helps to elucidate the implications of a wide variety of possible implementation pathways. It should be clear that the same option is likely to be implemented in widely different ways, depending on the underlying concept of justice, with two important kinds of repercussions.

First, different implementation pathways will result in quite different outcomes for cost and exposure. Second, an implementation pathway that is perceived as just from one perspective will be perceived as distinctly unjust from the others. For example, Option 6 (Section 5.1.6) calls for technology-based standards such as undergrounding and elimination of net currents. Implemented through a libertarian perspective, this might call for individual school districts to exercise primary responsibility for deciding when and how to achieve this standard and for funding through local bond issues and/or facilities budgets. Such an approach would appear plainly unjust from both utilitarian and social justice perspectives, since to the former it is an inefficient use of society's resources and to the latter perpetuates existing patterns of inequality. Conversely, if this option were to be implemented through a social justice perspective, it might call for identifying disadvantaged school districts and implementing the best available technological fixes immediately, funded by some income-neutral or progressive means, such as a general levy on electricity use. Such an approach would appear manifestly unjust from the perspective of both libertarian and utilitarian justice. To the former, this represents an undue infringement on freedom of action and to the latter an inefficient use of society's resources.

This discussion and Table 5.8 make it clear that some key questions of EMF policy for schools can only be settled by agreement on what system of justice (or combination of justice systems) should apply. These questions include:

- Should schools in poorer neighborhoods be fixed first, even if more lives might be saved by fixing the most cost-effective opportunities first?
- Should situations involving high-field exposures be fixed first, even if more lives might be saved by fixing more cost-effective opportunities first?
- Who should pay for EMF reductions in schools? Everyone? Just those with school children? Just the wealthy? Just those who want to pay? Just those whose equipment is responsible for the exposure?

Table 5.8 Schema for organizing possible implementation pathways. Table entries are illustrative examples of how basic differences in values lead to competing notions of how a given policy should be implemented. Entries in the "How1" and "How2" categories are explained further in this section and in Section 7, Options for Funding.

	Libertarian justice	***Utilitarian justice***	***Social justice***
Who focus on?	Those most concerned Those who can most easily pay	The most exposed	The least able to pay Those with least access to decision making Those most exposed to range of risks
What sources?	Whatever each district prefers	The largest contributor to exposure	The least controllable by school district (e.g., power lines)
When$_1$ initiate?	When each district prefers and/or can afford	When risk and uncertainty are balanced	As soon as possible
When$_2$ implement?	When each district prefers and/or can afford Schools selected by lottery	Priority to schools based on exposure	Priority to disadvantaged districts
Where implement?	First come, first served	Where EMF exposure/risk highest	Where cumulative risks highest
How$_1$ implement?	Exposure norm[1]	Cost-benefit[2] Observable risk[3]	Acceptable risk[4]
How$_2$ fund?	Costs born by those responsible for equipment creating exposure Costs born in proportion to mitigation needed Local bond issue Existing facilities budgets Pollution trading	Costs born equally by all: statewide bond issue state general fund	Costs born by those most able to pay: electric rates special utility tax utility gross revenue

Notes for Table 5.8**.**

1. Exposure norm: Choose a level of control so that school exposures are no larger than those encountered at home.
2. Cost-benefit: Choose a level of control so that the marginal cost of control equals the marginal willingness-to-pay for policy benefits (e.g., risk reduction, public confidence, etc.).
3. Observable risk: Choose a level of control to assure that no student is exposed above levels associated with increased risk in epidemiological studies (i.e., about 2 mG).
4. Acceptable risk: Choose a level of control so that residual risks (those remaining after mitigation is undertaken) are acceptably small.

5.5.3 Using policy options in combination

The policy options described in preceding sections represent examples of the kinds of tools government can use to accomplish goals such as those listed in Tables 3.1 and 3.2. Together with the funding approaches described in Section 7, these tools fall into the categories shown in Table 5.9.

Table 5.9. Categories of tools governments might use to accomplish policy goals such as those listed in Tables 3.1 and 3.2 (after John 1994).

Categories of Tools	**Characteristics**
Regulatory	Define and enforce rules of behavior Establish prohibitions and constraints Require specific actions Create liability Establish procedures
Catalytic	Exhort through symbolic action (e.g., speeches, goal setting) Motivate private and individual action
Resource transfer	
Public services	Provide information and education Operate broad-based public facilities and lands
Redistribution	Credits, payments, aid provided on basis of need or other criteria
Subsidies	Grants and loans Targeted technical assistance Construction of public facilities Insurance and guarantees Research and development

If further research demonstrates that EMF is a hazard (risk scenarios #1 or #2), then the nature of the EMF in schools problem makes it highly unlikely that regulation alone will accomplish the goals shown in Tables 3.1 and 3.2. This problem is characterized by a very large number of schools managed by local school districts that have a great degree of autonomy and independent statutory authority. There is a corresponding absence of any existing statewide authority with the means to monitor performance and enforce compliance at the level of individual schools. Any strictly regulatory approach that relies primarily on mandating standards and/or mitigation methods, and on enforcing these with conventional inspection and penalty mechanisms, therefore runs several kinds of risks.

First, strict statewide prescriptions will not be flexible enough to accommodate the wide range of specific circumstances found in schools statewide. These include variation in age, architecture, internal wiring, space usage patterns, and so on. Perhaps more important, districts will differ in the type and variety of other risks and needs they must trade off, the budgetary and human resources they have available to deal with these, and therefore in the relative priority they place on EMF exposures. Second, regulatory requirements alone, in the absence of the background information and technical support needed to implement these requirements effectively, will increase frustration among local decision makers whose "plates are already full" with existing operational, regulatory, and administrative requirements. Third, new regulatory requirements with no provision for funding will result in tightened resources at the local level and increased incentives for noncompliance. Fourth, a lack of available information and education about the nature of the risk and the options for dealing with it will increase skepticism about the reality and magnitude of the risk. This will, in turn, reduce local decision makers' motivation to address the problem and increase gaming behavior to avoid compliance.

The EMF-in-schools problem is characteristic of problems that are best dealt with through a combination of tools shown in Table 5.9. The risk and exposure management options described in Section 5.1 will be more successful if implemented by local decision makers interested in applying their knowledge to adapt statewide requirements to specific local situations. Thus, the success and acceptance of the exposure and risk reduction options will depend in most cases on qualitative factors that are best addressed through communication and procedural options. As a result, more comprehensive strategies, tailored to each risk scenario and including regulation, exhortation, education and information dissemination, as well as a variety of funding support, is much more likely to achieve policy goals.

For example, a targeted information program, developed in conjunction with specific exposure and risk reduction options, can help explain the rationale for the policy, show how it addresses stakeholders' primary concerns, and provide guidance for implementation. At earlier stages of development, research into stakeholder values can furnish insight into stakeholders' expectations and help determine effective implementation levels and pathways. In addition, a better understanding of stakeholders' perceptions and values can help predict likely responses to various options and implementation pathways. This in turn will aid in preventing unintended and/or perverse policy outcomes.

Certain of the communication and procedural options also mesh well with specific exposure and risk reduction options on a more practical level (Table 5.10). For example, standardized siting criteria could be a useful part of an overall policy to prohibit increases in exposure or to implement field standards on school grounds. This would depend on linking the policies by using the field standard or not-to-exceed level as the basis for calculating the siting distances for different types of transmission facilities. Where there might be disagreements over how to implement EMF standards, an expanded CEQA review process could provide a structured setting for examining and resolving these.

Implementing a majority of the exposure and risk reduction options will depend on a certain level of technical expertise within individual schools and school districts. Where this expertise does not exist, expanded technical services may be necessary for successful implementation. Clear design guidelines could meet some of this need in the cases of field and technology standards, and a requirement to enforce the electrical code.

In all cases, the availability of funding for implementation (see Section 8) will increase both the compliance with regulatory options and the usefulness of information and technical services.

Table 5.10. Shows which communication and procedural options support the development and/or implementation of specific exposure and risk reduction options.

	Information program	Research values	Standardize siting	Expand CEQA review	Technical services	Design guidelines
1. Eliminate programs	x	x				
2. Status quo	x	x				
3. Prohibit increases	x	x	x	x	x	
4. Field standards	x	x	x	x	x	x
5. Personal standard	x	x		x	x	
6. Technology standards	x	x		x	x	x
7. Enforce electrical code	x	x			x	x
8. Address all risks	x	x				

In terms of their complexity, the communication and procedural options fall into two groups. Developing an information program, researching stakeholder values, and standardizing siting guidelines are relatively less complex. Developing school design guidelines, providing additional technical services, and expanding the CPUC's CEQA review process are relatively more complex. All communication and procedural options are applicable to risk scenarios #1, #2, and #3, with the exception that Expand CEQA Review is not applicable to scenario #3, present uncertainty persists. The only option relevant to scenario #4 would be the information program, needed to explain why EMF programs are being terminated.

6. Quantitative Model of Field-Strength Standards

This section describes the structure and results of a computer model called EMF_SCHOOL to compare the costs and benefits of magnetic field standards in California schools. Here, we describe the goals of the EMF_SCHOOL model, its major assumptions and structural components, and its results. More details on the model can be found in the model's internal documentation and in a companion user's guide (Florig, 2000).

6.1 Modeling goals

EMF_SCHOOL was constructed to facilitate understanding and discussion among policy makers and stakeholders as they contemplate alternatives to manage magnetic field exposures in California schools. The model is implemented in Analytica (Lumina Decision Systems, Los Gatos, CA), a decision-support software package with a user-friendly graphical interface. The model addresses only policies that are applied to the State as a whole, and cannot be used to address EMF problems in any particular school. Although, as discussed in previous sections, there are many possible policies for addressing EMF in schools (e.g. field-strength standards, technology standards, risk standards), models to address each of these alternatives would share many features. EMF_SCHOOL focuses only on field-strength standards, but its key variables and sensitivities feature prominently in the consideration of other policies as well. By studying the problem of field-strength standards in some detail, stakeholders and policymakers can gain insight into other policy problems.

EMF_SCHOOL addresses only the costs and risk reduction benefits of alternative field level standards. The model does not address other attributes of possible importance (see Section 5.2) such as fairness, legal liability, and administrative effort. Because field strength standards would apply to all schools equally, they entail no fairness concerns in implementation. As with other policies that require expenditures, fairness concerns do enter in decisions concerning who should pay for implementation of field strength standards. The legal and administrative aspects of field strength standards are described in Section 5.2. These would not be expected to differ substantially across different levels chosen for the field strength standard.

Any model is an abstraction of reality. Our goal in modeling the costs and benefits of field-strength standards in schools is to create the simplest abstraction capable of providing insight into the most important features of the problem. These insights include (i) appreciation of the sensitivity of outcome variables (e.g. net benefits) to a variety of assumptions about exposure, health effects, and economics, (ii) understanding trade-offs between mitigation costs and various benefits of field-strength reduction, and (iii) developing a sense of what variables contribute most to decision uncertainty.

6.2 Model assumptions and structure

There are large uncertainties in the health risks of EMFs, smaller but significant uncertainties in EMF exposures from various sources, and perhaps an order of magnitude uncertainty in unit mitigation costs. Given these large uncertainties in a number of key model variables, improvements in the accuracy of other variables do not help inform the choice of policy alternative, but can add complications to the model, which make it harder to understand. We have made a number of simplifying assumptions consistent with preserving the gross behavior of the system. For instance, we consider only exposure in classrooms, because that is where children and staff spend most of their school time. Including less-inhabited areas would substantially increase costs, without commensurate reductions in exposure. Further, we consider only four sources - net currents, electrical panels, distribution lines, and transmission lines – because these four are the most important when population average exposure, chronic exposure to strong fields, and amount of public concern are used as source-selection criteria. According to Enertech's measurements, these four sources are together responsible for roughly 86% of classroom-average magnetic field exposures above 0.5 mG. In addition, these four sources span a wide range of mitigation costs, allowing for explorations of the cost-effectiveness implications of applying field-strength standards only to particular sources. EMF_SCHOOL does not address operator sources (e.g., electric pencil sharpeners, computers), even though the magnetic fields created by such sources are among the strongest found in schools. Operator would be important if EMF health risks were more closely related to peak exposures rather than to time-weighted average exposures. Although some operator sources create strong fields, the duration of exposure for operator sources and the number of people exposed to them is small compared to the four area sources included in EMF_SCHOOL.

The EMF_SCHOOL model includes only existing schools, not new schools. The focus on existing schools is based on the much larger population that would be immediately affected by policies concerning existing schools, as well as the fact that the costs of reducing EMF exposures in new schools is much lower than the costs of reducing exposures in existing schools.

Health risks are modeled for 21 diseases that are plausibly related to EMF exposure, based on existing literature. Because opinions vary greatly concerning the likelihood that these diseases are causally related to EMF exposure, the model represents each disease impact as the product of two factors, (i) the degree of certainty that EMF actually causes the disease, and (ii) the relative risk of the conditional EMF effect.

Exposures to power-frequency magnetic fields vary by the minute, hour, day, week, and season. Some scientists have noted that biological responses to magnetic field exposures might depend on some dynamic feature of exposure, or might occur only above some intensity threshold or within some intensity window (Morgan and Nair, 1992). Such hypotheses remain speculative, however. The EMF_SCHOOL model assumes that EMF health impacts, if real, are proportional to time-weighted average (TWA) magnetic field strength. TWA was chosen for the following reasons:

- TWA exposure is significantly correlated with risk in the EMF epidemiologic literature (Sheppard et al., 1999)

- There are scant data relating human risk to any particular non-linear measures of dose. Existing positive epidemiologic studies use only wire code, spot measurements, and/or computed time-averaged power line fields. Without better information to allow us to discriminate between one dose metric and another, we feel that there is little to be gained by modeling arbitrary non-linear metrics.
- Children are very mobile in school over time scales associated with disease induction (e.g. months if not years). A child whose desk is in an elevated field today will be at a desk in low field the next hour, week, month, or year.
- There are no time-activity data for the 89 schools in the Enertech dataset. Therefore, one cannot estimate any dose metric that would require information about where people spend time.

Although we use only TWA exposure in our model, we account for the possibility of other dose measures by including a factor that allows users to degrade the calculated effectiveness of mitigation measures (estimated using TWA), based on the extent to which users judge the true dose metric to be unrelated to TWA magnetic field exposure. For instance, if users judge the correlation between TWA exposure and the “true” dose measure to be only 50%, then the risk reduction attributed to a given exposure standard will be reduced by half from what would be estimated using TWA.

EMF_SCHOOL estimates exposure and risk attributable to school time only. As no data are available on non-school exposures for those attending the 89 schools in the Enertech database, there is no way to examine correlations between exposures at school and elsewhere. Thus, we have no way of knowing whether students who attend schools with higher than average fields are more or less likely to live in homes with higher than average fields.

EMF_SCHOOL estimates school-time time-weighted average exposure using the spatial distribution of magnetic fields in classrooms. Because students and staff spend the majority of their time in classrooms, ignoring other areas is not expected to introduce significant error in the estimate of TWA exposure. For purposes of estimating population risk, EMF_SCHOOL uses the population-average of each individual's TWA magnetic field exposure. The population- and time-weighted average does not depend on how often students are shuffle between desks or move between classrooms.

For a given relative risk and degree of certainty that EMF causes a given disease, EMF_SCHOOL estimates savings in deaths, disease cases, and disability-adjusted life-years (DALYs). The DALY is a method for combining morbidity and mortality effects into a single index of disease burden (Anand and Hanson, 1997; Murray and Acharya, 1996; Murray and Lopez, 1996). Morbidity and mortality reduction in DALYs is computed by summing life-years lost from premature death and a weighted fraction of the number of years lived with disability. Details on how EMF_SCHOOL computes DALYs can be found in the EMF_SCHOOL User's Guide (Florig, 2000).

The EMF mitigation costs to implement a standard would be incurred within several years after such a policy is put in force, but the resulting health savings would extend throughout the physical lifetime of a school. We assume a default value of 30 years for this lifetime. In order to compare mitigation costs and health savings, health savings are monetized using a willingness to pay to avoid a lost DALY. Health savings that happen in the future are discounted to the present using a discount rate for risk reduction. Details are available in Florig 2000.

6.3 Model Implementation

EMF_SCHOOL is implemented in Analytica,[3] a graphically-oriented programming language designed especially for doing policy analysis. Models in Analytica are represented graphically as influence diagrams. Users can investigate model details simply by clicking on nodes of the influence diagram that represent variables of interest. Analytica incorporates uncertainty by representing input and output variables as probability distributions. This makes it possible to tell whether differences in the net benefits of two policy alternatives are significant in light of the uncertainty in the estimates of those outcomes. Analytica is designed so that models can be internally documented. Variables are displayed with both a mathematical definition and a verbal description.

6.4 Policy Options Modeled

EMF_SCHOOL estimates the costs of benefits of 60-Hz magnetic field standards applied to public school classrooms. Classrooms alone are considered because that is where students and teachers spend most of their time. The model computes costs, benefits, and cost-effectiveness for each source separately and for all sources together, to allow for consideration of standards applied only to particular sources. The model computes results for all schools, and for elementary and middle/high schools separately, to allow for consideration of standards applied only to particular student age-groups.

EMF_SCHOOL computes results for standards of 5 mG, 2 mG, 1 mG, and 0.5 mG. We choose these levels merely as convenient mile markers for expressing model output across the range of plausible field strength standards. We consider only standards up to 5 milligauss, because there are so few exposure situations above that level that statewide costs and benefits are small. We do not model the ICNIRP [4] field limit (2 Gauss) because it is indistinguishable in cost and benefit from no limit (the status quo). We do not

[3] Analytica is available from Lumina Decision Systems, Los Gatos, California. A demonstration version of Analytica can be downloaded for free from their website at www.lumina.com.

[4] The ICNIRP (Intl. Commission on Non-ionizing Radiation Protection) guidelines appear in Health Physics, Vol. 74, (4):494-522 (April '98).

explicitly list a "no standard" option because no standard is the status quo. By definition, the model computes changes in costs and benefits from the status quo.

In their survey of magnetic field levels in schools, Zaffanella and Hooper (2000) identified ten classes of magnetic field source. For simplicity, EMF_SCHOOL models exposure from four of these that, together, account for 86% of the spatially-averaged classroom magnetic field level above 0.5 milligauss. These sources are net currents, electrical panels, distribution lines, and transmission lines. Including other sources would slightly increase estimates of both the benefits and costs of exposure reduction (see Figs. 12.5 and 12.6 in Zaffanella and Hooper 2000).

Standards can be based on either average or worst-case fields in classrooms. Results for standards applied to power-line exposures are computed using spatial-average fields in classrooms because power-line fields are relatively uniform across a classroom dimension. For standards applied to net currents or electrical panels, however, the user can choose to apply a standard based on either the spatial-average classroom field or the 95^{th} percentile field (i.e. the source field exceeded in only 5% of the classroom space). In a classroom with 20 children, 5% of the area would represent the desk area of one child.

6.5 Uncertainty, Variability, Values, and Judgment

EMF policy models contain many kinds of uncertainty. Some parameters are well-known, but vary across the population (e.g. average classroom exposures in elementary versus high schools). Some parameters are uncertain because measurements are sparse (e.g. number of students in California chronically exposed to fields > 5 milligauss). Other parameters are uncertain because the science is complicated (e.g. dose-response coefficient for childhood leukemia). Finally, some parameters are uncertain because they are matters of value (e.g. willingness to pay for life-saving interventions) or of judgment (e.g. probability that EMF health effects are real). In the EMF_SCHOOL model, these various kinds of uncertainty are treated either by assigning probability distributions to variables or by representing variables by a set of discrete values from which the user can choose. To reduce computational complexity, EMF_SCHOOL uses point estimates (best estimates) whenever uncertainties are relatively small (e.g. number of students in California schools).

EMF_SCHOOL includes both objective quantities (e.g. background levels of EMF exposure in classrooms) and subjective quantities (e.g. the probability that EMF health effects are real, willingness-to-pay for investments in life-saving interventions) in the interest of being inclusive of the factors that figure strongly in peoples' calculus. Key variables are represented using a range of values from which the user can choose, according to their own judgment. In addition to facilitating discussion on costs and benefits of possible standards, EMF_SCHOOL allows users to do a variety of sensitivity analyses to explore which factors are most critical to the endpoints of interest.

6.6 Model Structure, Inputs and Outputs

EMF_SCHOOL contains six modules that (1) define school characteristics, (2) establish background exposure levels and exposure reductions resulting from standards, (3) estimate background health status and estimate health improvements resulting from standards, (4) value those health improvements in monetary terms, (5) estimate mitigation costs, and (6) compute various measures of policy performance such as net benefits, cost-effectiveness, life-years saved, and the value of waiting. Details of the structure of each of these modules can be found in the EMF_SCHOOL model users guide (Florig, 2000). Inputs to EMF_SCHOOL, which may be adjusted by the user, include parameters for estimating exposure, risk, mitigation efficacy, cost, discounting, and the value of morbidity and mortality savings. Outputs from EMF_SCHOOL include estimates of exposure reduction, risk reduction, and mitigation cost as a function of the level of exposure standard. All outputs are indexed by disease type, age group, school type, and EMF source type. Morbidity and mortality savings are converted to disability-adjusted life-years to allow both to be expressed on the same scale, combined, and valued.

6.7 EMF_SCHOOL Model results

6.7.1 Population exposure reductions

As mentioned above, EMF_SCHOOL models magnetic field exposure for four of the most significant magnetic field sources in schools: net currents, electrical panels, distribution lines, and transmission lines. According to measurements by Zaffanella and Hooper (Zaffanella and Hooper, 2000), these four sources contribute 86% of classroom-average magnetic fields exceeding 0.5 mG.

The exposure reductions resulting from various field-strength standards applied to sources individually or together are shown in Figure 6.1 . These results show that net current mitigation becomes increasingly dominant as a contributor to exposure reductions as field-strength standards are reduced. These results also show that field-strength standards that focus only on power lines would eliminate less than about 15% of the total population exposure in classrooms, and that standards for transmission lines alone would address less than 2% of all population exposure. Finally, even at 0.5 mG, field-strength standards eliminate only about 60% of classroom exposures from all sources.

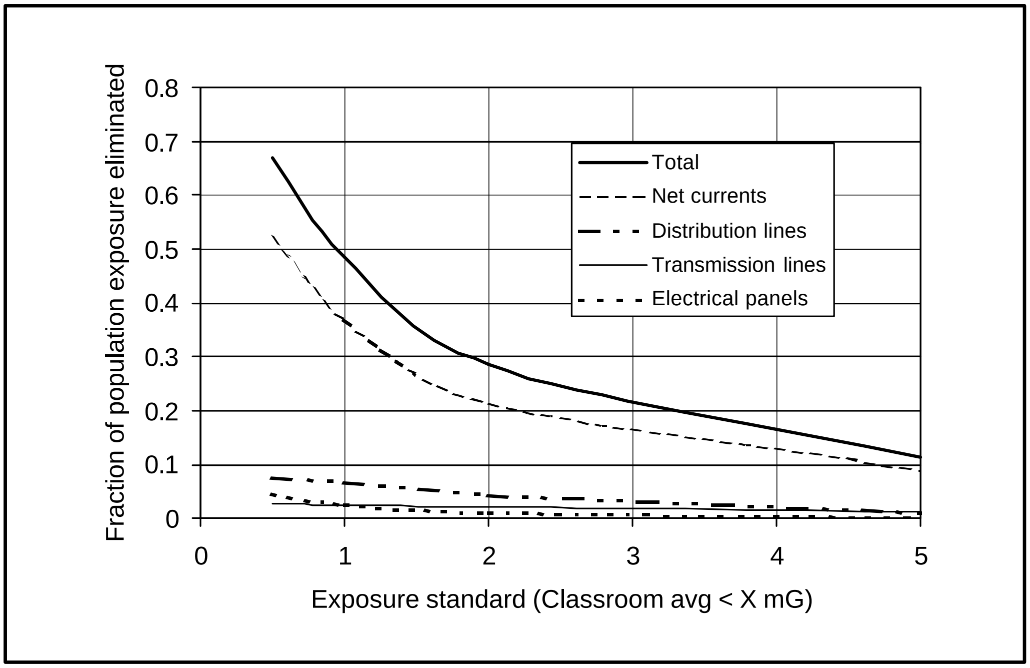

Figure 6.1. Fraction of baseline population exposure eliminated by field-strength standards for classroom average fields.

In response to a field strength standard, all of California's 7,700 public schools would presumably be required to survey magnetic fields to determine if any classrooms were out of compliance with the standard. Table 6.1 shows the approximate number of schools that would have at least one classroom that is out of compliance with a given standard. For a 2 mG standard based on the spatial average classroom field, it is estimated that roughly 2400 schools would have to take action to reduce field levels.

Table 6.1. Approximate number of schools that would be affected by field-strength standards applied to each of four sources. There are roughly 7700 public schools in California.

Source	**Standard for classroom average & 95% field**		
	1 mG	2 mG	5 mG
Net currents	4000, 6000	1800, 5000	500, 2000
Electrical Panels	400, 6000	100, 4000	0, 1200
Distribution lines	700, 1000	300, 400	60, 170
Transmission lines	300, 400	200, 300	70, 100

6.7.2 EMF risk reductions

Conditional on the existence of one or more EMF health effects, EMF_SCHOOL estimates morbidity and mortality reductions by disease resulting from implementation of various field-strength standards. In this section, we describe the sensitivity of these estimates to various parameters.

6.7.2.1 Disability-adjusted life-years (DALYs)

Estimates of morbidity and mortality reductions resulting from a given exposure standard depend on assumptions concerning the degree of certainty that a given disease is caused by EMF exposure and the dose-response coefficient for a given age group. For a given relative risk and degree of certainty that EMF causes a given disease, EMF_SCHOOL estimates savings in deaths, disease cases, and disability-adjusted life-years (DALYs) associated with that disease. The DALY is a concept for combining morbidity and mortality effects into a single index of disease burden and has been used widely by national and international health authorities (Anand and Hanson, 1997; Murray and Acharya, 1996; Murray, 1994). DALYs associated with a given condition are computed by adding the years of life-expectancy lost from premature death to the years of healthy life lost from disability, with the latter discounted to account for the fact that disability is less severe than death. Thus, the loss of DALYs associated with a sudden accidental death of an 80 year old with 5 years of additional life expectancy would be the same as the DALYs lost from a 65 year old living another 20 years with a chronic disease resulting in a 25% disability. For details on how EMF_SCHOOL computes DALYs, readers should consult the EMF_SCHOOL Users' Guide (Florig, 2000).

Table 6.2 shows the 21 diseases considered by the model, ranked by disease burden (DALYs) in the California school population. This table also lists morbidity rates and mortality rates for each illness (excluding life-years lost from death).

It is, of course, highly unlikely that all of these 21 conditions are caused by EMF exposure. The estimates of disease burden, however, are indicative of relative EMF impact, should any of these diseases be found to be caused by EMF. That is, given identical assumptions for all diseases about the relative risk of EMF exposure and the degree of certainty that EMF causes the disease, those diseases that have the largest EMF impacts will be those with the highest background disease burdens. These include conditions that have high background incidence rates, cause death at a young age, and/or are associated with long and severe periods of disability.

Table 6.2. Diseases plausibly linked to EMF, ranked by total disease burden in the California school population. Morbidity and mortality estimates are age-adjusted. Cancer morbidity from 1989-1993 CDHS, Cancer Surveillance Section. Mortality data from "Vital Statistics of California 1992," State of California, Department of Health Services (1994). Others from (Sheppard et al., 1998). Latency periods are estimates from the California State Department of Health Services staff.

Disease	Annual morbidity (cases per 10^5)		Annual mortality (deaths per 10^5)		DALYs per case (excl. lost life-yrs)		Disease burden (DALYs per year)		Latency period (yrs)	
	Stud.	Staff	Stud.	Staff	Stud.	Staff	Stud.	Staff	Stud.	Staff
Spontaneous abortion	0	0	220	800	0	0	900,000	110,000	0	0
Low birthweight	50	200	0	0	17	17	41,000	6,700	0	0
Perinatal mortality	n.a.	n.a.	5.3	25	0	0	21,000	3,500	0	0
Suicide	n.a.	n.a.	2.2	15.4	0	0	7,400	1,500	0	0
Leukemia	3.3	8.9	1.7	52	0.3	0.4	6,200	420	3	5
Cor.onary heart disease	0.1	700	0.01	72	0.02	0.02	34	5,300	0	0
Lung cancer	0.04	70	0	48	0.4	0.3	0.83	3,500	0	20
Cardiac arrythmia	1.0	12	0.1	3.5	0.02	0.02	350	2,500	0	0
Brain/CNS	2.4	6.9	0.61	5.2	0.4	0.3	2,400	410	3	20
Alzheimers disease	0	70	0	.45	0	12	0	2,300	n.a.	20
Breast cancer, female	0.01	80	0	16	0.4	0.4	0.21	1,940	3	10
Non-Hodgkins lymphoma	1	17	0.22	5.4	0.25	0.25	800	420	3	5
Unipolar major depression	50	320	n.a.	n.a.	0.17	0.17	450	150	0	0
Hodgkins	1.4	2.9	0.13	0.62	0.2	0.3	500	59	3	5
Melanoma	0	60	0	3.0	0	0.2	0	270	n.a.	30
Prostate cancer	0	50	0.01	4.2	0	0.6	19	210	n.a.	20
ALS	0.025	1.3	0.025	1.3	1.6	1.6	94	100	5	0
Wlims tumor	0.2	0	0.01	0	0.4	0	47	0	1	n.a.
Breast cancer, male	2.0	0.4	0	0.07	0.4	0.4	43	3.1	3	10
Testicular cancer	0.35	3.0	0	0.15	0.6	0.6	12	13	5	10
Neuroblastoma	0.002	0	0.001	0	0	0.4	3.3	0	1	n.a.

6.7.2.2 Mortality savings

Of all the diseases that are plausibly linked to EMF exposure, leukemia has the most epidemiologic evidence for an EMF connection. Figure 6.2 presents the estimated mortality savings from a statewide exposure standard for schools, conditional on the EMF-leukemia effect being real. Mortality savings rise increasingly rapidly with more stringent field-strength standards because the number of people exposed at lower magnetic field levels is much greater than the number exposed at higher levels. Note that present equivalent deaths avoided represents mortality savings over an assumed 30-year physical lifetime of the mitigation measure, discounted to the present. The discount rate used in this example is 5%. Note too that a relative risk of 5 confers less than (5-1)/(1.1-1)=40 times the mortality savings of a relative risk of 1.1, because the model accounts for current levels of mortality from EMF background levels.

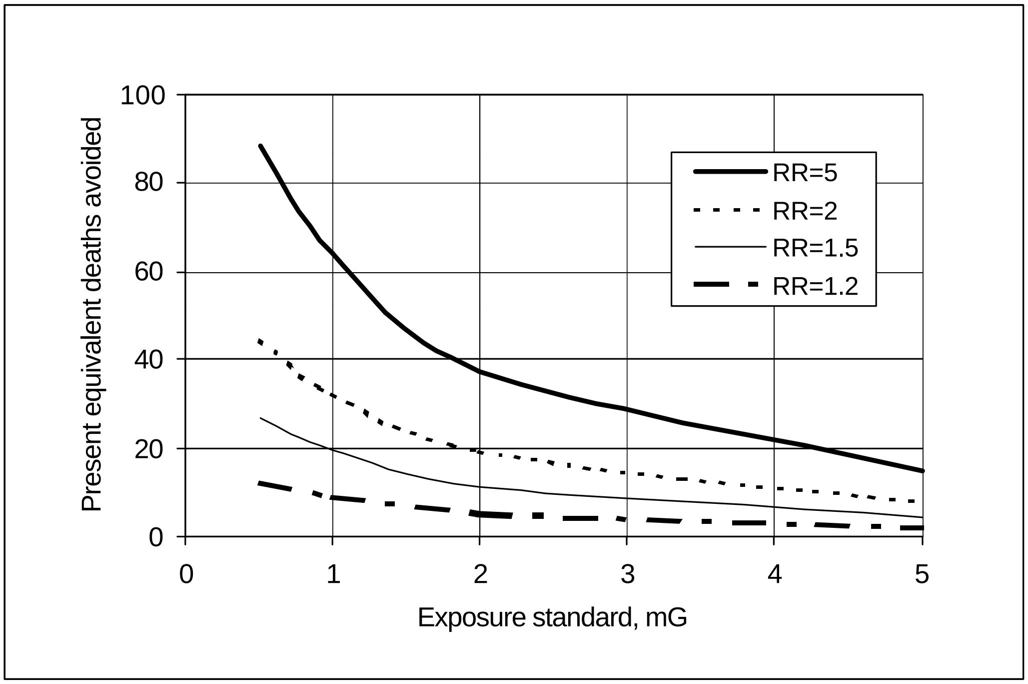

Figure 6.2. Present equivalent leukemia deaths avoided vs. exposure standard for classroom average field, by relative risk (RR) of 2 mG TWA exposure compared to 0 mG. The "present equivalent" is the discounted sum of future deaths over the physical lifetime of the mitigation. (degree of certainty=1, mitigation efficacy=100%, powerline fraction=medium, mitigation lifetime=30 years, discount rates=5%).

By way of comparison, the mortality savings in Figure 6.2 are from an all-cause total of 2,200 present equivalent expected leukemia deaths (about 100 per year) among California school children and staff.

The mortality savings in Figure 6.2 are presented for the case in which the degree of certainty parameter is set to one, corresponding to a belief that EMF definitely causes leukemia. To represent more skeptical beliefs, we consider degrees of certainty to less than one (but greater than zero). In that case, mortality savings is represented by a two-part probability distribution. One part looks like the curves in Figure 6.2. The other part is zero. So, for example, if one believes that there is only a 10% chance that EMF causes leukemia, then the PE mortality savings from a 2 mG standard, assuming a relative risk of 2 (as in Figure 6.2) would be a 10% chance of 20 deaths averted and a 90% chance of zero deaths averted. EMF_SCHOOL can express any of its mortality-related output variables in either this two-part form, or as an expected value, which is simply a weighted average of the zero and non-zero portions (0.1*20=2.0 PE deaths averted in the example above). This expected value representation is used in all the results presented below, for cases in which the degree of certainty is less than one.

The mortality savings in Figure 6.2 represent the case in which risk is proportional to time-weighted averaged (TWA) magnetic field exposure. To account for the possibility of a non-TWA relationship between EMF exposure and risk, EMF_SCHOOL attenuates exposure reductions calculated using TWA by a percentage set by the user. Thus, if one believes that reducing time-weighted average exposure will reduce risk only by half the amount predicted by the ratio of TWA exposure reduction to premitigation TWA exposure, then this can be specified. So, the mortality savings in Figure 6.2 would have to be reduced not only by the degree of certainty parameter, but also by this efficacy of mitigation parameter.

6.7.3 Baseline EMF risks in schools

To compute risk reductions that result from EMF standards, we first estimate the exposure reductions resulting from a given standard, and then use our dose-response model to estimate morbidity and mortality savings. It is also possible to use our dose-response model to estimate the pre-mitigation EMF risk levels in schools, subject to the many uncertainties in EMF bioeffects. Figure 6.3 presents estimates of annual leukemia mortality from school-time EMF exposure, as a function of the assumed strength of the dose-response relationship (i.e. relative risk of chronic 2 mG exposure) and the degree of certainty that EMF is indeed a leukemia hazard.

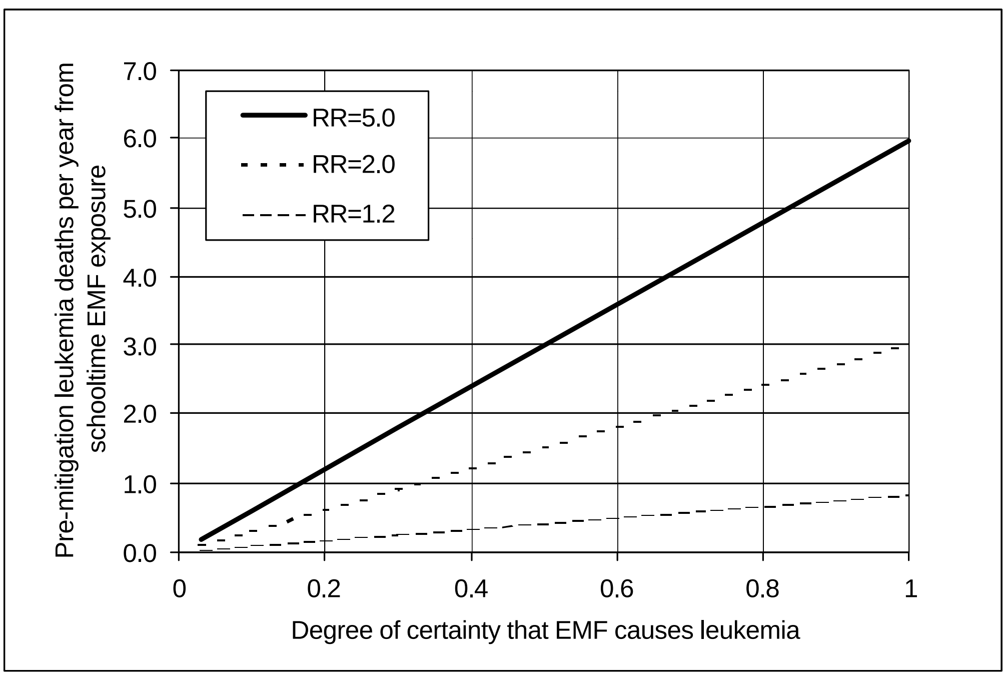

Figure 6.3. Expected value of pre-mitigation annual leukemia deaths from classroom EMF exposure versus relative risk and degree of certainty(powerline frac=med).

6.7.4 Survey and mitigation costs

EMF_SCHOOL bases estimates of survey and mitigation costs for net currents, electrical panels, and power lines on the unit cost estimates provided by Enertech Consultants (Zaffanella and Hooper, 1998; Zaffanella and Hooper, 2000). To account for possible biases in Enertech's estimates of unit costs, users of EMF_SCHOOL can adjust a "mitigation cost multiplier," which increases or decreases Enertech's unit costs by some factor ranging from 0.1 to 10. More details on how EMF_SCHOOL estimates costs can be found in the EMF_SCHOOL User's Guide (Florig, 2000).

Although the Enertech data are accurate for the purpose of estimating costs for field-strength standards that are well within the range of common field levels (e.g. < 3 mG classroom average), uncertainties rise with increasing field strength, because the 89 school data base contains relatively few cases at higher field levels. To address this problem, we fit probability distributions to data at lower levels, and estimate the number of cases at higher field strengths using the tails of these distributions. The specifics of our cost-estimation sub-model are different for different source types. These details can be found in the internal documentation of the EMF_SCHOOL model itself and in the EMF_SCHOOL users guide.

6.7.4.1 Mitigation cost by source and exposure standard

Mitigation cost estimates from EMF_SCHOOL by source and exposure standard are shown in Figure 6.4, taking Enertech's unit costs for survey and mitigation as given. As would be expected from the principle of diminishing returns, mitigation costs grow more steeply with decreasing standard levels. Taking Enertech's unit costs as given, statewide mitigation costs for all sources range from about $40 million for a 5 mG standard to about $240 million for a 0.5 mG standard. Under a medium estimate for the fraction of schools that are close to power lines, mitigation costs for net currents and electrical panels are significantly higher than those for distribution and transmission lines. Under a high estimate (not shown) for the fraction of schools that are close to power lines, however, mitigation costs for transmission lines exceed those for other sources for field-strength standards of 2 mG or less. Again, using Enertech's estimates of the unit costs of EMF surveys, EMF_SCHOOL estimates statewide survey costs for all sources combined to range from $8-11 million, depending on the exposure standard level. Thus, survey costs comprise less than 20% of the total costs of applying EMF field-strength standards to all sources.

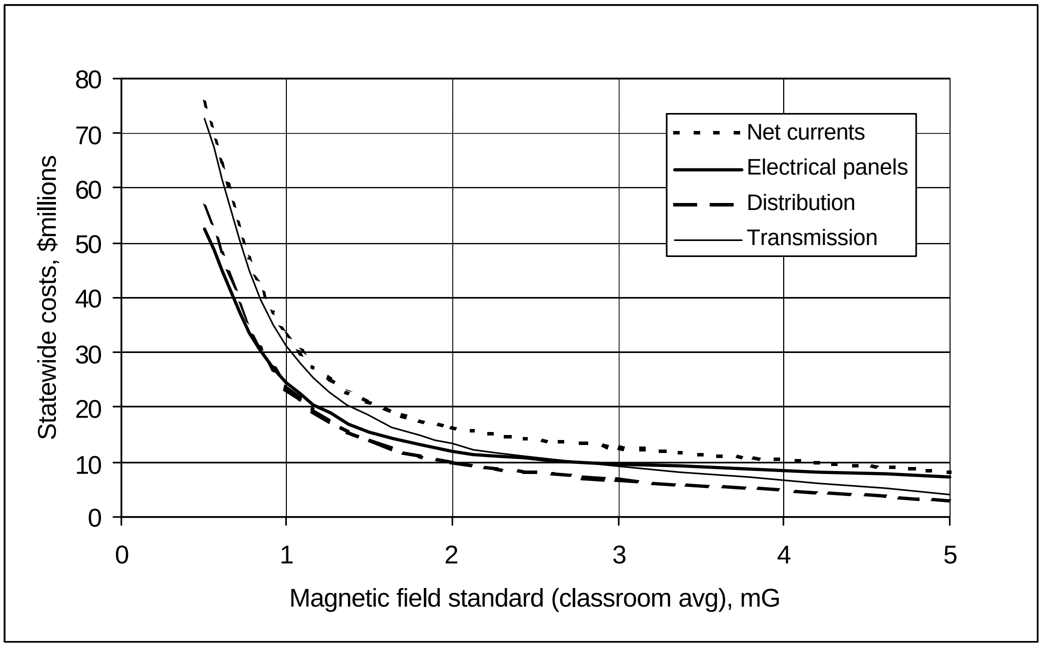

Figure 6.4. Statewide survey & mitigation costs vs exposure standard by source. Assumes separate survey for each source. (powerline fraction=med, spat crit=avg<stnd, mit cost mult=1)

6.7.5 Cost effectiveness analysis

Cost-effectiveness is often used as one criteria of policy merit. Cost-effectiveness is the cost of a policy divided by its benefits. In the case of EMF management programs, cost effectiveness can be measured in dollars per disability-adjusted life-year saved. A cost effective policy is not necessarily an inexpensive policy, a policy that affects many people, or a policy with large benefits. A cost effective policy is one that produces high returns per unit of investment. By prioritizing investments in health and safety protection by cost-effectiveness, society can maximize the amount of life-saving those investments produce.

Research has shown that the cost-effectiveness of lifesaving interventions varies over a wide range. A 1997 study by Tengs et al. of the cost-effectiveness of 139 government lifesaving interventions found cases ranging from hundreds of dollars per life-year saved to tens of millions of dollars per life-year saved, with an average across all interventions of $44,000 per life-year (Tengs, 1997). EMF_SCHOOL calculates cost effectiveness of field-strength standards in dollars per present equivalent disability-adjusted life year saved. As described in Section 6.2 , disability-adjusted life-years provide a means to combine morbidity and mortality savings into the same measure. Estimates of the cost-effectiveness of field-strength standards are sensitive to assumptions about both health savings and costs. Figure 6.5 shows EMF_SCHOOL's estimates of the cost effectiveness of field-strength standards applied to classrooms, assuming that (i) the EMF leukemia hazard is real and results in a relative risk of 2 at for chronic exposures to 2 mG, (ii) mitigation costs are the same as Enertech's best estimates, and (iii) the efficacy of mitigation is 100% of what would be expected based on a time-weighted average dose measure. These results show that field-strength standards for net currents and distribution lines are significantly more cost-effective than those for transmission lines and electrical panels. All sources except net currents show increasing marginal costs with more stringent standards. The minimum in the cost-effectiveness curve for net currents results from survey costs being a substantial portion of total cost at high field levels. These curves can shift upward substantially if mitigation costs were to be much greater than Enertech estimates or if the EMF-leukemia connection is weaker than assumed here. In fact, if it is less than 100% certain that EMF causes disease, then the expected value of cost-effectiveness goes to infinity. Likewise, these curves can shift substantially downward if mitigation costs were to be much lower than Enertech estimates, or if other diseases in addition to leukemia were associated with EMF exposure.

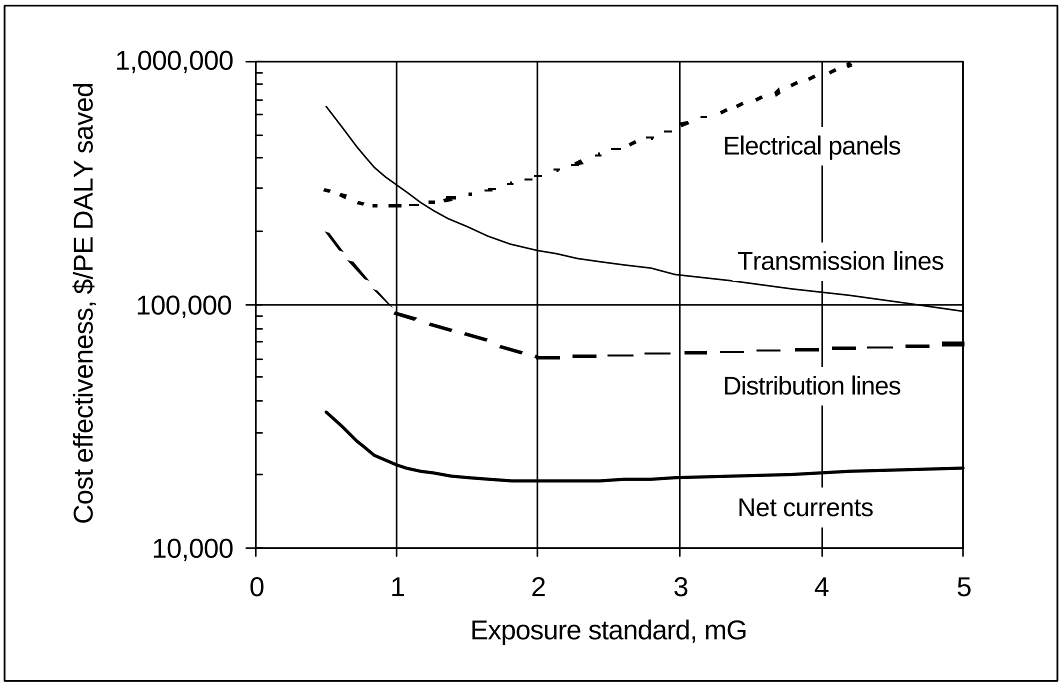

Figure 6.5. Cost-effectiveness of exposure standards in classrooms, by EMF source. (degree of certainty=1, RR_2=2, disease=leukemia only, avg<std, mitigation efficacy=1, frac close=med, cost multiplier=1)

6.7.6 Cost-benefit analysis

The cost-effectiveness results described above examine the cost of realizing a given amount of risk reduction. Another criterion that is often used to evaluate policy alternatives is the difference between policy benefits and policy costs. In the case of risk management policies, benefits are estimated by placing a monetary value on each unit of risk reduction, discounting any future risk reductions to the present. This valuation step is subjective. In a companion document (Sheppard et al., 1998) to this report, Sheppard et al. review a number of methods that economists commonly use to perform these valuations. Not surprisingly, each method produces a wide range of estimates for the value of risk reduction. In the EMF_SCHOOL model, the user can select from a number of alternative values, and explore the implications of each. The model expresses risk reduction in disability-adjusted life-years (DALYs) (Murray and Acharya, 1996). The values that the model can assign to one DALY range from $10,000 to $250,000. This range is consistent with the value of lifesaving implicit in many government regulatory programs (Tengs, 1997; Tengs et al., 1995). Although society invests heavily to protect children in schools, there are limits to what society has been willing to spend. Only a few states require seat belts in school buses, for instance, because, at approximately $2.8 million per life-year saved, seat belts have presumably not been viewed as the best use of limited school resources. By contrast, society has fully implemented seat belt requirements for the center rear seat in automobiles at an estimated cost of $1.9 million per life-year saved.

Figure 6.6 presents cost-benefit results from EMF_SCHOOL, illustrating how the net benefits of field-strength standards vary with the stringency of the standard, the source to which it is applied, and the willingness to pay for risk reduction. These results, which are based on the assumptions that EMF causes only leukemia (at a relative risk of 2 at 2 milligauss TWA exposure) and that Enertech's control costs are accurate, show that net benefits for all four sources swing from negative to positive as willingness-to-pay for risk reduction changes from $10k per DALY to $250k per DALY. Depending on assumptions and sources, net benefits for a 2 mG exposure standard, for instance, could range from -$20 million to +$200 million. The cost-benefit results in Figure 6.6 show that field-strength standards applied to net currents have the most positive net benefits of the four sources considered, whereas transmission lines have the least positive net benefits.

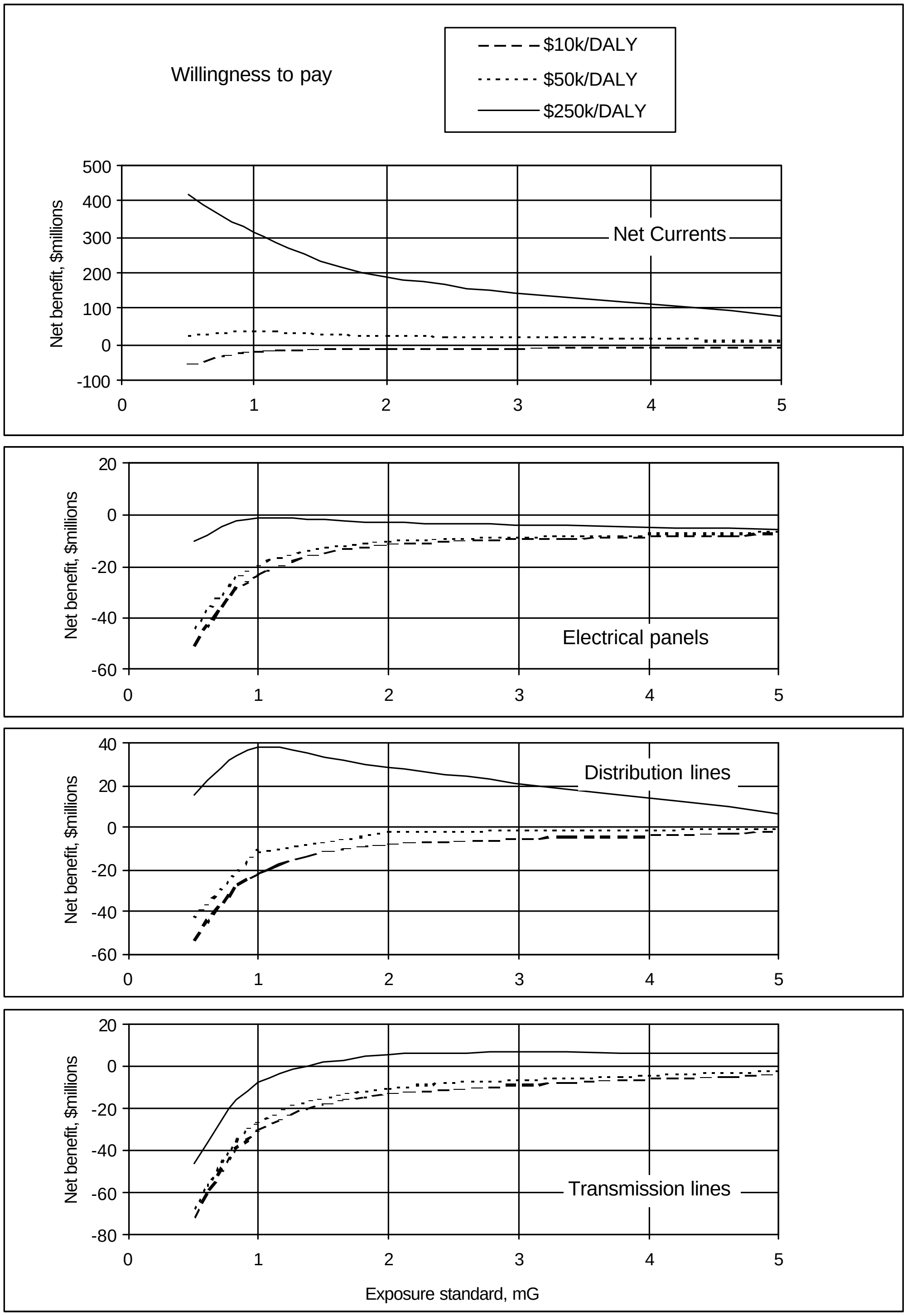

Figure 6.6. Net benefits of classroom exposure standard vs willingness to pay per disability-adjusted life-year (DALY) saved, assuming EMF causes only leukemia. (RR_2=2, degree of certainty=1, average<standard, mitigation efficacy=1, fraction of powerlines close=medium)

The next figure (Figure 6.7) illustrates the sensitivity of these results to the disease under consideration. Despite the greater number of children compared to staff, and despite the greater number of lost life-years resulting from a child death compared to an adult death, some adult diseases have large enough background rates that net benefits of EMF mitigation can be much larger for the adult disease than for the childhood disease. Figure 6.7 shows that, with the same assumptions for relative risk and degree of certainty, the net benefits from reductions in coronary heart disease (CHD) and suicide are each greater than the net benefits from reductions in leukemia.

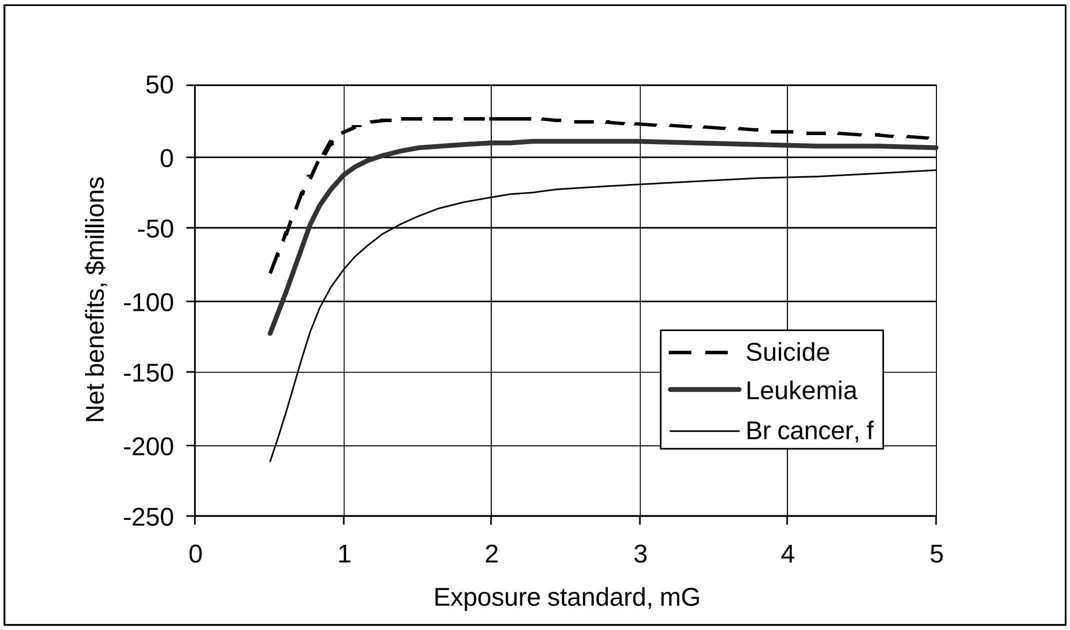

Figure 6.7. Sensitivity of net benefits to disease type, assuming that a time-weighted average exposure of 2 mG conveys a disease risk twice as great as a time-weighted average exposure of zero. Untoward pregnancy outcomes (not shown) have net benefits in the +$billions if assigned 75 lost life-years per event. (sources=all, RR_2 =2, degree of certainty=1, avg<stnd, mitigation efficacy=1, fraction of powerlines close=medium, WTP=50k).

6.7.7 Value of Waiting

Using the approach described in Section 5.2.6, we estimated the value (positive or negative) of delaying the decision on whether or not to impose standards. The results, shown in Figure 6.8 for one particular combination of input parameters, illustrate how waiting can have either positive or negative benefits, depending on one's degree of certainty concerning health effects. Changes in other variables (e.g. the types of diseases considered, source type) can also greatly shift the expected benefits of waiting.

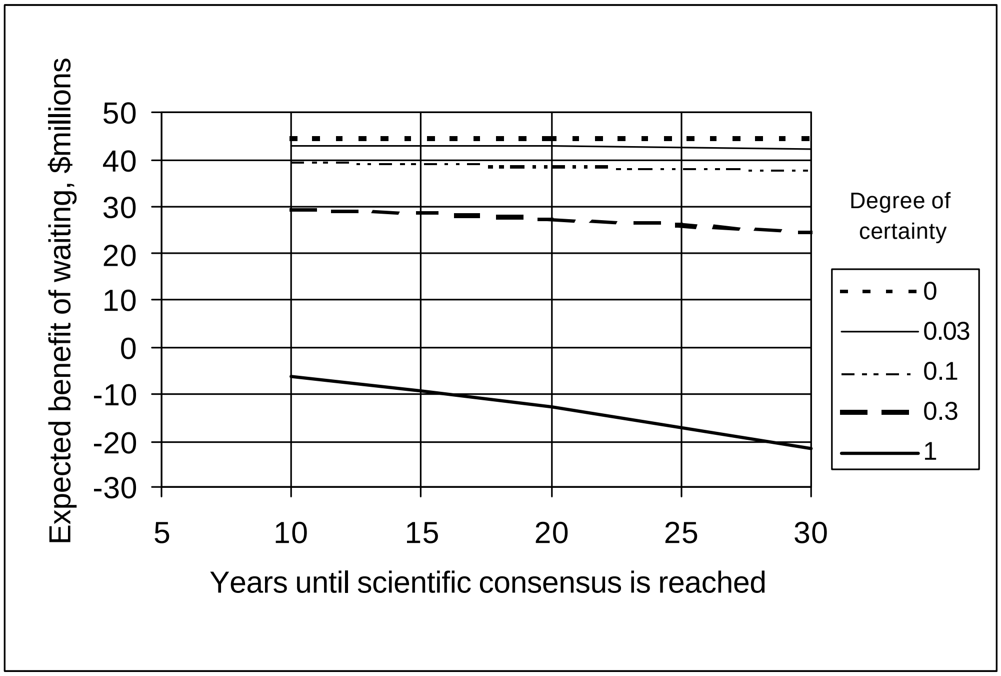

Figure 6.8. Benefit (or cost) of delaying decision until scientific consensus is reached. (Leukemia only, Standard=2 mG, RR_2=2, net currents only, avg<stnd, mitigation efficacy=1, cost multiplier=1, fraction of powerline close=medium, wtp=$50k/DALY)

6.8 Summary of model results

The EMF_SCHOOL model (and the Enertech measurements on which the model's exposure estimates are based) provides a number of useful insights that apply broadly to policies for managing EMF exposure in schools.

Magnetic fields in schools are, on average, comparable to or slightly smaller than magnetic fields in homes. Typical schoolwide classroom average fields are about 0.5 mG. Roughly 10% of schools have classroom average fields exceeding 1 mG. Less than 1% of schools have classroom average fields exceeding 2 mG.

Only a few sources contribute the lion's share to EMF population exposure in schools. In order from greatest to least population exposure, the four most significant area sources in classrooms are net currents, distribution lines, electrical panels, and transmission lines. Although as many as 15% of schools have transmission lines within 100 meters of school property, less than 1% of classrooms have magnetic fields from transmission lines that exceed 0.5 mG in at least 5% of the area.

Both individual and population exposures are important in considering policy alternatives. Measurements by Enertech suggest that about 16,000 students and staff statewide are chronically (6 hours per school day) exposed to classroom EMF levels above 5 mG. Using a time-weighted average dose measure, this cohort represents only 15% of the total schooltime population exposure from EMF. The fractions of schooltime population exposure eliminated by field-strength standards of 5 mG, 2 mG, 1 mG, and 0.5 mG are roughly 15%, 27%, 40%, and 55% respectively.

The disease impact of EMF exposure depends not only on the strength of the causal association between EMF exposure and a particular disease, but also the loss of healthy life-years associated with a given condition. For a given relative risk of EMF exposure and a given degree of certainty of EMF effect, diseases producing the greatest loss of disability-adjusted life years are depression/suicide, coronary heart disease, and leukemia.

Of all the diseases possibly associated with EMF, the scientific evidence is strongest for leukemia. Assuming the leukemia risks are proportional to time-weighted average magnetic field exposure and assuming worst-case leukemia risks from EMF (e.g. relative risk of 5 for chronic exposures of 2 mG), the maximum mortality savings from a 2 mG exposure standard for schools would be about 2-3 deaths avoided per year statewide. The savings would be about half as large for a relative risk of 2.

Of all the input parameters of EMF_SCHOOL, those with the biggest influence on the cost effectiveness and net benefits of field-strength standards are (i) the degree of certainty that a particular disease is associated with EMF exposure, (ii) the relative risk of EMF exposure, (iii) the actual efficacy of mitigation relative to that calculated using time-weighted average field levels, (iv) the mitigation cost multiplier, and (v) willingness to pay for risk reduction.

Based on societal norms for cost-effectiveness of lifesaving programs and willingness to pay for lifesavings, EMF field-strength standards appear favorable for some sources under some assumptions, but not others. In general, field-strength standards for net currents and distribution lines are much more cost-effective than field-strength standards for electrical panels and transmission lines. The average cost-effectiveness and net benefits of field-strength standards are only a weak function of the standard level because, as standards are made more stringent, both costs and exposure savings rise at similar rates. As most net currents arise from violations of the National Electrical Code, meeting field strength standards for net currents would presumably reduce risks of electric shock, fire, and equipment damage from overvoltage. Adding these co-benefits would make addressing net currents even more cost-effective than estimated by EMF_SCHOOL.

Compared to an "act now" strategy, waiting until scientific consensus is reached on whether EMF exposure is hazardous has positive net benefits under conditions of lower degrees of certainty concerning health impacts. For low degrees of certainty, waiting becomes more beneficial as the exposure standard is applied to more sources and as the standard becomes more stringent. Whether it is better to act now or to wait is relatively insensitive to expectations about the number of years (10-30) until scientific consensus is reached.

7. Options for Funding

The intent of this section is to present information about possibilities for funding options that may be selected for implementation. Much of Sections 7.1 and 7.2 is adapted from Appendix D in (National_Res_Council, 1997).

7.1 Taxes

In general, taxes can be levied on income, property, and goods and services. Personal and business income is taxed by national, state, and some local governments and rates may be progressive or flat. Income taxes create incentives for those taxed to reduce their liabilities by changing the form or the place in which income is earned, or by changing the amount of effort expended in earning taxable income.

Personal property taxes (e.g., real estate, boats, automobiles) are a common revenue raising mechanism for local governments. Real estate taxes are considered appropriate for financing general local government services enjoyed by all residents (e.g., police and fire protection), but Proposition 13 in California has put limits on the extent to which they can be used. As a result, they are increasingly being supplemented by specific user fees. Property taxes create incentives to reduce taxes by changing the form and place in which wealth is held.

Taxes on goods and services (sales taxes) are widely used and include taxes on many consumer items. Broad-based sales and value added taxes are like consumption taxes or income taxes with exemptions for savings. In addition, excises are sometimes levied on specific commodities to provide revenues for government programs related to the commodity (federal gasoline taxes) or to discourage consumption (excises on alcohol and tobacco, for example). If the market price of an activity does not fully reflect its full economic costs, a tax on it may improve the allocation of resources by reducing excessive demand.

7.1.1 Electricity production and/or pollutant tax

Because electricity use is the source of concern about potential risks from EMF exposure, taxes on electricity production and/or use may be viewed as an equitable method for financing both the capital and operating costs of responding to these concerns. Production or use taxes are common in other arenas. For example, taxes on gasoline and diesel fuel finance the Federal Highway Trust Fund, and similar taxes finance both the national air traffic control system and the Inland Waterways Trust Fund. This kind of production or use tax is based on the premise that certain costs are inherent in maintaining socially or economically important infrastructure and services and that the users of these should bear a part of these inherent costs.

Pollutant taxes, in contrast, reflect the "polluter pays" principle and are based on the premise that a specific constituent is known to cause harm to people and/or the environment. Several states impose a variety of such taxes. Florida, for example, imposes a Coastal Protection Tax of 2 cents per barrel on pollutants (e.g., petroleum products, pesticides, chlorine and ammonia) produced in, or imported into, the state. Washington imposes a tax of 0.7 % of the wholesale value of the product on pesticides and consideration has been given to basing the amount of the tax on toxicity, persistence and bioaccumulation of the pesticide. Proceeds from such taxes can go to the state's general fund or be earmarked for specific activities through trust funds or other mechanisms. The continued existence of the tax can be contingent on the amount of money raised or on external events that increase the need for mitigation.

7.1.2 Impact taxes and development fees

Impact taxes and development fees are charged on goods or activities that are known or presumed to have an impact on public resources. Development fees for new construction are typically assessed to cover the cost of new or upgraded infrastructure (e.g., roads, utilities), services (e.g., fire, police, schools), and amenities (e.g., parks, libraries). Such fees, or impact taxes, can be levied for each specific item or as a lump sum for all public costs related to development. Similar fees can be levied on redevelopment activities as well. The basis for calculating these fees and impact taxes can vary. They might be based on per unit charges per living unit, square foot, or land area, excise taxes on construction materials, gross receipts taxes on contractors and developers, or a rezoning tax based on the category to which the land is zoned and the number of acres involved. The amount of revenue raised would of course depend on the amount of development activity.

7.1.3 Land tax or fee on transmission rights of way

Taxes or fees on transmission line rights of way could provide funds for reducing EMF from transmission lines, but would probably not be perceived as a fair mechanism for raising funds for all EMF sources in schools. A right-of-way tax or fee would be collected from all utilities for all transmission lines, but would be used to fund EMF exposure reduction only for those lines near schools.

7.1.4 Sales tax surcharge

Sales tax surcharges are often established at both the local and state level to provide funds for specific needs.

7.1.5 State general revenue fund

Mitigation and other policy options could be financed directly from the state's general revenue fund, through the normal budgetary process.

7.2 Bonds

Bond financing allows private or public bodies to spread the cost burden of the program or project over a long period of time. In some instances the program created as a result of the bond issue will provide enough revenue to pay off the bond, but in other instances general tax revenue will be required for repayment. Thus, the project must have enough political support within the jurisdiction to win approval, since the people of the designated area pay for the bond through higher taxes or user fees. States and "special districts" or regions are authorized to issue bonds yielding interest that is exempt from federal taxation to finance programs with some recognized national public interest.

7.3 Surcharge on electric rates

A utility rate surcharge could be enacted to pay for EMF exposure mitigation and other policy options. Rate surcharges bear some resemblance to production fees and pollutant taxes (see Section 7.1.1). However, they are targeted primarily at the end user, rather than the producer, and reflect the principle that the consumers of electricity should pay for the external costs of its use.

Surcharges could be a flat fee or could be based on a sliding scale in which the amount either increases or decreases with increasing usage, cost of providing service, or other considerations. Historically, rate surcharges were set as part of the general rate cases for each utility and were typically used to fund public purpose programs such as providing rate relief for low income utility customers. Such surcharges have been set both by the California State Legislature and the PUC, with the final level sometimes resulting from negotiation and/or litigation between the two. Once the overall size of the surcharge was established, an often complex allocation process would determine the relative shares to be paid by the utilities shareholders or its customers. The allocation process would also determine whether all customers would be charged an equal amount or whether the size of the surcharge would depend on electricity usage and/or the cost of providing service. In general, the starting point for these negotiations has been that the bulk of any surcharge mandated by legislation should be passed through to customers. In some cases, however, the legislation mandating the surcharge has stated that shareholders shall pay for all or part of the surcharge.

The deregulation of California's utility industry is likely to change this process. Transmission, distribution, and generation will now be managed and regulated separately. Transmission will be regulated by FERC (Federal Energy Regulatory Commission), distribution by the CPUC, and generation largely by the market. In the future, the cost of surcharges imposed by legislation would most likely continue to be passed through to ratepayers and these surcharges could still be collected by the local utility. However, the actual mechanisms through which this would be accomplished are not clear, including what portion of the total cost of electricity the surcharge would be based on, nor how (or if) transmission and generating companies will contribute to the utility's share of any surcharge. In addition, the change from cost-based to performance-based rate making, along with the increased influence of competition on rates, will most likely lead utilities to strongly resist the inclusion of additional items in their budgets. The terms of deregulation have also made it very difficult for utilities to pass costs to shareholders.

In summary, there was a predictable mechanism and set of principles for defining rate surcharges and their allocation to ratepayers and shareholders. New approaches to ratemaking under deregulation, including the increased influence of market pressures, have clouded the picture of how costs associated with any EMF mitigation would be recovered. Such mechanisms will have to be developed anew under the new regulatory structure.

7.4 Utility gross revenue (including modify PUC Rule 20)

Utilities could be required to pay for EMF exposure mitigation and other policy options directly from their revenue stream. Depending on the circumstances, these costs could be part of the rate base or not.

7.5 Other sources of funding

Financing of many public and environmental goods and services through the traditional means described above (e.g., taxes, grants, bond issues) is becoming increasingly difficult. The increasing pressures on government budgets and the reduction or elimination of many funding sources creates an incentive to develop alternative sources of financing.

Alternative financing is based on the principle that the capital to implement a project will follow, once a steady, reliable source of revenues to repay the costs of implementation has been found. Revenues are any stream of funds collected periodically, but reliably, for services or benefits rendered. They can be generated in many ways, including the taxes, development fees, and surcharges described above, as well as the examples provided below. The more predictable and certain the revenue stream, the more suited it is for debt repayment and program maintenance and the more likely it is to attract sources of capital. Such sources can include the bond market or any capital market; banks and other financial institutions such as insurance, finance and leasing companies; and private investors such as corporations, foundations, and individuals. A few suggestions for identifying steady, reliable sources of revenues are outlined in the following sections.

7.5.1 Special assessment districts

A special assessment district is an independent government entity formed to finance governmental services for a specific geographic area. These districts can range in size from a city block to a multijurisdictional arrangement. Special districts provide needed structure, management, and financing and focus the costs of enhanced services on the beneficiaries of those services by separating benefited taxpayers from general taxpayers. Residents of special districts pay taxes (usually in the form of increased tax rates) to finance improvements from which they will benefit. Special districts have the power to levy taxes and to collect fees and special assessments to pay for development and operation of desired programs. Because they can issue debt independent of region or state, special districts can reduce the burden on general debt capacity.

7.5.2 Tax increment financing

This technique depends on the presence of a special district where a government-financed enhancement has benefited the residents of the district. From then on, two sets of tax records are maintained for the district, one that reflects asset values prior to the enhancement, and a second that captures any growth in assessed property value in the district after the enhancement. Tax revenues collected on the increased values of the properties after the improvement can be diverted to pay for the cost of the government-financed program in the special district. In some cases, governments issue tax-increment bonds for revitalization projects, with the bond being backed, in part, by the anticipated increase in property values resulting from the investment. This approach would be applicable in cases where concerns about EMF exposure had lowered property values and where residents were willing to include local schools in any mitigation effort.

Tax-increment financing differs from a special assessment district in its treatment of underlying property tax rates. Property tax rates are increased in a special assessment district to cover improvements made in the district. In contrast, underlying property tax rates may not be inreased in special districts utilizing tax-increment financing. Instead, additional revenues are collected based on increased assessed property values enjoyed after the improvements are made.

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